ECONOMIC DETERMINANTS OF MULTILATERAL ENVIRONMENTAL AGREEMENTS AND THEIR TIMING

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Xinping Tian

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ECONOMIC DETERMINANTS OF MULTILATERAL ENVIRONMENTAL AGREEMENTS AND THEIR TIMING

Approved by:

Dr. Tibor Besedeš, Advisor
School of Economics
Georgia Institute of Technology

Dr. Haizheng Li
School of Economics
Georgia Institute of Technology

Dr. Erik Johnson
School of Economics
Georgia Institute of Technology

Dr. Juan Moreno-Cruz
School of Economics
Georgia Institute of Technology

Dr. Daniel Matisoff
School of Public Policy
Georgia Institute of Technology

Date Approved: July 7, 2016

To my parents

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SUMMARY

This dissertation examines the economic factors that contribute to countries' cooperation on multilateral environmental agreements (MEAs). Our results indicate that extensive economic interactions may help countries overcome potential free-riding problems and work together on international environmental issues. We first examine the likelihood a pair of countries enters into the same MEA as well as the number of MEAs they both share using a near universe of agreements. We then separately examine the MEAs dealing with pollution issues and those dealing with resource issues. At last, we examine how long it takes two countries to have their first agreement since 1950 and how long it takes them to have an additional one conditional on already having had some agreements. Our MEA data come from Ronal Mitchell's International Environmental Agreements Database (2002-2016).

The main results are summarized as follows. First, we find that two countries are more likely to have an MEA or have more of them if they are economically larger and of similar economic size, closer in distance, have a preferential trade agreement, and trade more. These results are strongest for environmental agreements between a small number of countries. Second, we show that these economic factors have similar effects on the formation of pollution related agreements and resource related ones. We also show that there exists a spillover effect between countries' cooperation on these two types of agreements. Third, we find that economic size, distance, and trade integration variables shift the hazard of two countries having their first agreement as well as subsequent ones.

Moreover, we show that countries' likelihood of cooperating on an additional agreement is much larger than the likelihood of having their first one.

CHAPTER 1

INTRODUCTION

In recent decades, international environmental issues such as climate change, biodiversity, and acid rain become more and more severe and urgent. Since no single country can resolve such problems alone, countries often coordinate through legal multilateral environmental agreements. However, we observe that some countries cooperate on a large number of such environmental agreements while other countries cooperate less or never cooperate. This dissertation explores the economic factors that may influence countries' coordination on multilateral environmental agreements as well as the timing of their coordination. Its contributions are as follows.

First, we are among the first to identify the economic determinants of multilateral environmental agreements. We find that countries' economic size, distance, economic integration levels, and the common resources they share play an important role in their coordination on environmental agreements. We examine the environmental agreements based on the number of signatories they have. Our results are most robust and consistent for the agreements among a small number of countries.

Second, this dissertation sheds light on the economic determinants of the formation of multilateral environmental agreements as well as international agreements in general. In international trade literature, factors like economic size, distance, and economic integration levels also influence the formation of trade agreements. Our results indicate that these economic factors may contribute to countries' international negotiations in general.

Third, we examine the economic determinants of environmental agreements dealing with pollution issues and natural resource issues separately. Basically, even though some economic factors have different effects on pollution agreements and resource ones, most factors influence these two types of agreements in a similar way. Moreover, there exists spillover effect among countries' coordination on pollution and resource agreements.

Fourth, we employ a discrete-time duration analysis to examine the timing of multilateral pollution agreements. We find that factors such as economic size and distance shift the hazard of two countries having their first agreement and the subsequent ones. In addition, we show that the hazard of having an additional agreement conditional on already having had some agreements is much higher than the hazard of having the first agreement.

The dissertation is structured as follows. Chapter 2 examines the economic factors that lead to multilateral environmental agreements (MEAs) being formed. We examine the likelihood a pair of countries enters into the same MEA as well as the number of MEAs they both share using a near universe of agreements from Ronal Mitchell's International Environmental Agreements Database (2002-2016). We separately examine MEAs with fewer than the sample median number of signatories (26), MEAs with greater than the 3rd quartile number of signatories (68), and all the MEAs in the sample. Our approach is motivated by a hypothesis that environmental agreements with a small number of signatories are more likely to be initiated in order to deal with common pool resource issues. As such, these agreements are more likely to have binding commitments and, as a result, are more likely to be affected by economic determinants. Larger agreements, such as those signed by virtually all countries in the world, may be agreements largely expressing an intent and desire to deal with an issue, but embody no binding commitments for countries which sign them. The determinants of such agreements may not be economic in nature. Our results show that two countries are more likely to have an MEA or have more MEAs if they: 1) are economically large and of similar economic size, 2) are closer to each other in distance, 3) have a preferential trade agreement, and 4) have larger bilateral trade flows.

Chapter 3 separately examines the economic determinants of pollution related agreements and resource related agreements. Pollution related agreements mainly deal with pollution affecting air, land, oceans, or freshwater system. Resource related agreements include those dealing with natural resource, habitat, freshwater resource, ocean, and species. The former category addresses various forms of pollution, while the latter one mainly focuses on the conservation of natural resources. We find that economic size, distance, trade agreements, and bilateral trade flows have statistically significant effects on countries' coordination on both pollution related agreements and resource related agreements. These results are most robust for the MEAs between a small numbers of countries. In addition, we find the evidence that countries' cooperation on pollution agreements may contribute to their cooperation on resource agreements and vice versus.

The last chapter employs a discrete-time duration model to explore the economic determinants of timing of pollution related agreements. Specifically, we examine how long it takes two countries to have their first agreement since 1950 and how long it takes them to have an additional one conditional on already having had some agreements. Following the method developed by Hess and Persson (2012), we employ a discrete-time duration model to examine the hazard of two countries' cooperation on pollution agreements in the period 1950 to 2005. We focus on all the pollution agreements in our sample, as well as the agreements with a small number of signatories and those with a large number of signatories. Our results indicate that economic size, distance, and trade integration variables shift the hazard of two countries having their first agreement as well as subsequent ones. In addition, the time variable has a positive effect on the hazard conditional on two countries having no agreements before, but the effect changes to be negative if two countries already have some agreements. Furthermore, countries' likelihood of cooperating on an additional agreement is much larger than the likelihood of having their first one.

CHAPTER 2

ECONOMIC DETERMINANTS OF MULTILATERAL ENVIRONMENTAL AGREEMENTS

2.1 Introduction

In recent decades, there has been an enormous surge in the number of multilateral environmental agreements that countries use to address transboundary environmental issues they cannot resolve alone (see the first column in Figure 2.1). From 1950 to 2012 countries negotiated over 1100 such agreements to deal with various environmental issues including global warming, acid rain, degradation of habitats, and overfishing among others (Mitchell 2002-2014). In this paper we empirically investigate the economic determinants of the formation of multilateral environmental agreements.

Previous empirical literature investigating multilateral environmental agreements (MEAs) mainly focuses on factors that influence a single country's decision to ratify a specific environmental treaty (see Fredrikson and Gaston, 2000; Neumayer, 2002; Egger et al., 2011, 2013; Millimet and Roy, 2014). General results show that countries that are wealthier, have a more democratic political system, and most importantly, are more open to trade are more likely to ratify an MEA. Our effort departs from the current literature by examining two countries' cooperation on a near universe of multilateral environmental agreements, rather than focusing on a small number of them or focusing on a single country's ratification of a particular agreement.

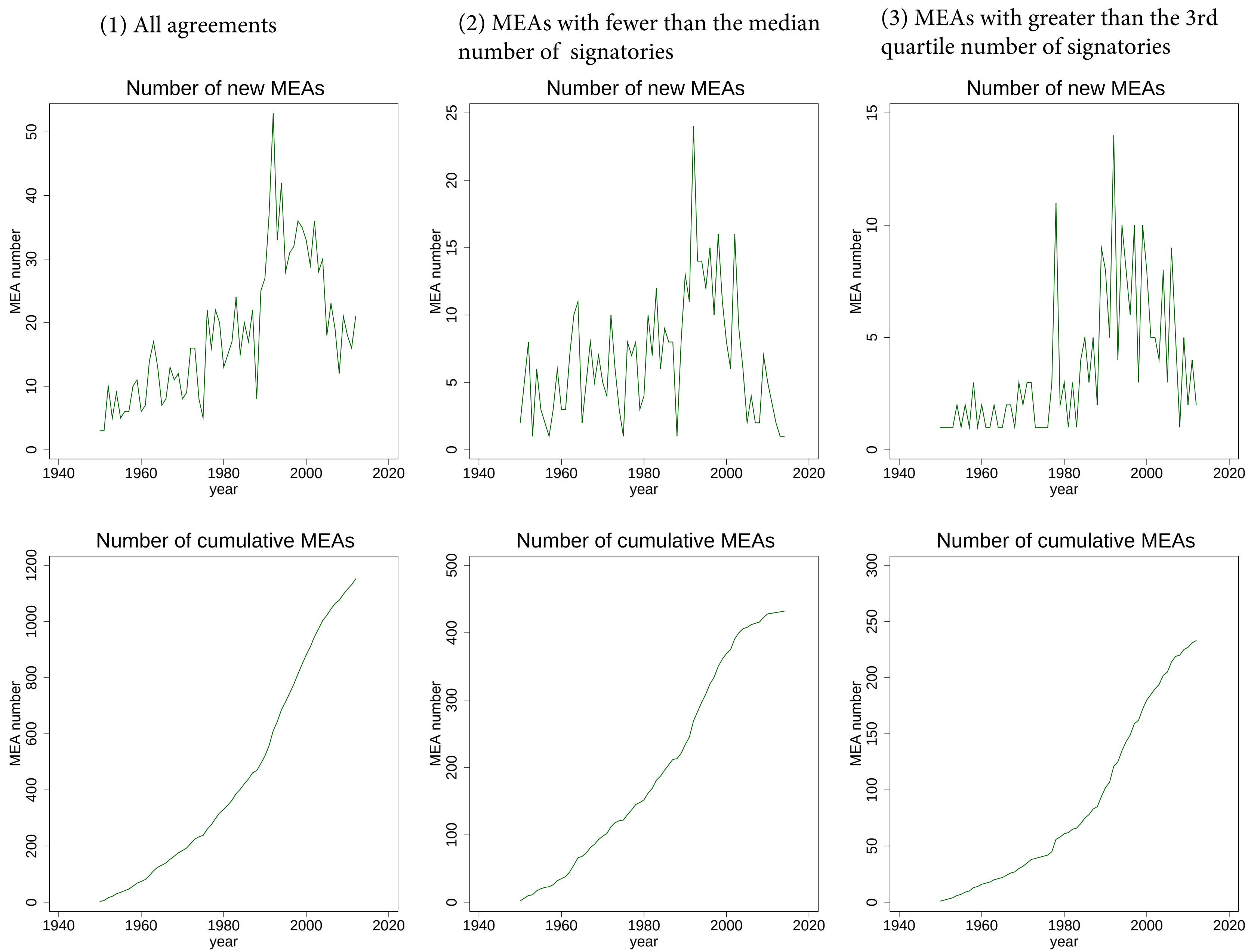

Figure 2.1 Annual count of multilateral environmental agreements

We examine countries' cooperation on solving transboundary environmental issues through the prism of formation of multilateral environmental agreements. Specifically, we ask two questions: which factors determine the likelihood of two countries having a multilateral environmental agreement and which factors determine the number of multilateral environmental agreements they share? For example, in our data France has ratified 213 MEAs prior to 1990. Among these agreements, France and Germany are both parties to 179; France and Mexico are parties to 69; and France and Slovakia have no common MEA at all. Instead of focusing on a single country's MEA participation as done in the previous literature, we investigate why some countries cooperate more on environmental issues (like France and Germany) and why other countries cooperate less or never cooperate (like France and Mexico or France and Slovakia).

We use a specification motivated by the gravity equation to explain countries' cooperation on multilateral environmental agreements. We find that GDP, distance, and preferential trade agreements, variables that usually explain bilateral trade flows well in the gravity equation literature in international trade, are also good predictors of the probability of two countries having a multilateral environmental agreement as well as the number of agreements they have. Our results indicate that countries trading more with each other are more likely to be parties to at least one environmental agreement. This might not be an intuitive result. Countries that mitigating emissions or protecting endangered species may incur economic losses. For example, restricting emission of pollutants like carbon dioxide might hurt their firms' competitiveness in the global market as new regulation increases the cost of production. Moreover, cooperating on some environmental agreements may result in less trade between countries. As a result, countries trading more with each other might avoid joining MEAs together as it may have a large negative effect on their trade.

On the other hand, it may be easier for countries to link their cooperation on economic policies to environmental policies when their economic interactions are large. Two countries can discuss environmental issues and economic issues simultaneously, since such linkage may sustain more cooperation on both issues (Limão, 2005). A country not interested in protecting the environment may be willing to do so if it can enjoy benefits from reduced trade barriers from its trading partners. Countries with extensive economic interactions have more opportunities for such linkages than countries with fewer interactions. In addition, countries may suffer non-environmental costs if they choose not to cooperate on an environmental agreement (Hoel and Schneider, 1997). For instance, a country might be excluded from future trade agreements if it refuses to cooperate on an environmental agreement. Trading partners will be more willing to participate in environmental treaties if the benefits they obtain, such as a decrease in tariffs or forming a free trade agreement, are larger than the costs they incur.

We separately examine MEAs with a few signatories and those with a high number of signatories. Specifically, we examine: 1) MEAs with fewer than the sample median number of signatories (26); 2) MEAs with greater than the 3rd quartile number of signatories (68); and 3) all the MEAs in our sample. Environmental agreements in our data have as few as 3 and as many as 197 signatories. Figure 1 shows the temporal evolution of new MEAs as well as their cumulative number for the three aforementioned groups.

There are two reasons that we separate MEAs based on the number of their signatories. First, theoretical papers exploring the formation of the multilateral environmental agreements predict that self-enforcing environmental agreements could sustain a large number of signatories only when the difference in net benefits between the non-cooperative and fully cooperative outcomes is very small (Barrett, 1994). A general rule is the smaller the actual commitment, the larger the set of participants (Sandler, 1997). Based on this theoretical prediction, we can expect that countries often bear smaller economic costs on average when they ratify large environmental treaties than they do when they ratify small environmental treaties. In addition, some large treaties such as the Framework Convention on Climate Change are signed by almost all countries in the world but have no specific abatement obligations. This means that countries that ratified them bear almost no cost at all. Since we examine factors that determine the likelihood of two countries having an MEA, the existence of such symbolic large treaties may bias our results.

Second, small environmental agreements and large ones often deal with different kinds of environmental issues. Agreements with a few signatories primarily deal with regional environmental issues such as cross-border air pollution or overfishing in regional seas. Agreements with a large number of signatories often deal with global environmental issues such as climate change or endangered species. To be more precise, both of these reasons speak to the central hypothesis we investigate in this paper – that environmental agreements with fewer signatories are signed by countries which desire to deal with common pool resource issues, while larger ones are most likely what one may call "statement" or "preference" agreements in which countries express a desire to deal with an issue but make no strict commitments. With such demarcation of agreements in mind, economic and geographic factors are much more likely to be a driving force behind the formation of smaller agreements.

We estimate our specifications annually from 1980 to 2000 allowing us to compare the temporal stability of the determinants. As mentioned above a country's ratification of MEAs may affect its GDP, trade, and its cooperation on various trade agreements. All of these factors present potential endogeneity problems in estimation. To deal with these issues, we use the 1970 data on GDP, trade agreements, and bilateral trade flows, similar to the approach used by Bergstrand et al (2014). Our results show that two countries are more likely to have an environmental agreement as well as have more environmental agreements if they are economically larger and of similar economic size, are closer to each other in distance, have a preferential trade agreement, and trade more with each other. These results are most robust and consistent over time for MEAs with a small number of signatories. For large treaties, the economic factors have mixed, if any, effects.

Our results suggest that countries' economic interactions may help them overcome potential free-riding problems to work together on transboundary environmental issues. In addition, since the ratification of MEAs often require countries to impose more stringent environmental standards, extensive economic interactions may also help offset the unfavorable "pollution haven effect."

2.2 Related Literature

There are a large number of game-theoretic papers exploring the formation and characteristics of international environmental agreements. Much of this literature focuses on whether a stable coalition forms (Libecap, 2014). Non-cooperative game theory is a very popular approach (e.g. Barrett, 1994, 1997, 2001; Carraro and Siniscalo, 1993, 1998; Hoel, 1992; Hoel and Schneider, 1997; Rubio and Ulph, 2003; Finus et al 2005). This literature mainly uses the concept of internal and external stability. Internal stability means that no coalition member or signatory of an MEA has an incentive to leave the agreement to become a non-signatory. External stability means that no non-signatory party has an incentive to join the MEA.

Most non-cooperative game theoretic models of MEAs draw a rather pessimistic picture of the prospect of successful cooperation between countries (Finus and Maus, 2008). Basic results show that the number of countries in a stable coalition is likely to be very small and that self-enforcing international environmental agreements with a large number of signatories may not be able to improve substantially beyond non-cooperative outcomes.

A number of papers empirically investigate the formation of multilateral environmental agreements (Fredriksson and Gaston, 2000; Neumayer, 2002; Beron et al., 2003; Murdoch et al, 2003; Egger et al, 2011, 2013; Millimet and Roy, 2014; Davies and Naughton, 2014). Most papers examine the role of trade liberalization in countries' participation decisions. Egger et al. (2011) investigate the effect of trade liberalization on countries' participation in multilateral environmental agreements. They use a linear feedback model to analyze the dynamics of the number of environmental agreements a country ratifies and construct a variable measuring trade liberalization from a non-linear regression model. The results show that a country will ratify more multilateral environmental agreements if it is economically larger and has more liberalized trade and investment policies.

Davies and Naughton (2014) examine whether proximate countries have greater incentives to cooperate than distant ones in the presence of cross-border pollution. They use spatial econometrics to estimate participation in 110 international environmental treaties by 139 countries over 20 years. They find that the higher the treaty ratification by a country's neighbors, the more treaties the country will ratify itself. In addition, their results are most evident in regional environmental agreements.

Millimet and Roy (2014) examine whether the World Trade Organization (WTO) and its predecessor the General Agreement on Tariffs and Trade (GATT) have a 'chilling effect' on participation in MEAs. To consistently estimate this 'chilling' effect, two econometric issues need to be addressed: self-selection in the GATT/WTO and the difficulty of actually classifying GATT/WTO. The authors use a partial identification approach to tackle these problems. The results show that one cannot exclude the possibility that GATT/WTO has no causal effect on MEA participation for the full sample. WTO does have a negative effect on MEA participation by less developed or non-OECD countries.

Our paper is also related to the literature on formation of international trade agreements. There is a large body of empirical research investigating the formation of free trade agreements (Baier and Bergstrand, 2004; Egger and Larch, 2008; Baldwin and Jaimovich, 2012; Chen and Joshi, 2010; Bergstrand et al., 2014). Baier and Bergstrand (2004) provide one of the first systematic empirical analysis of economic determinants of the formation of free trade agreements. The main conclusions are that the potential welfare gains and the likelihood of a FTA between two countries are higher the smaller is the distance between the two trading partners, the more remote two continental trading partners are from the rest of the world, the jointly economically larger and more similar are the two trading partners, the greater is the difference in capital-labor endowment ratios between the two countries, and the smaller is the difference in capital-labor endowment ratios of the member countries relative to that of the ROW.

To analyze the effect of pre-existing preferential trade agreements (PTAs) on non-members' incentives to participate in a PTA, Egger and Larch (2008) test three hypotheses: (1) the formation of a PTA and its enlargement generate incentives for non-members to join an existing PTA; (2) there are also incentives for non-members to establish a new PTA; (3) these interdependencies decrease with distance. By using spatial econometric techniques, they find significant support for their hypotheses.

2.3 Econometric Model

We use two econometric methods to analyze the economic determinants of multilateral environmental agreements. We estimate a probit model to examine the factors which influence the likelihood of two countries having at least one environmental agreement. We then estimate an ordinary least square model to examine the factors that influence the number of environmental agreements they have. An observation in our data is a pair of countries in a given calendar year.

The econometric framework used in the first method is the binary choice model. Let y^* denote a latent variable which is the value of a multilateral environmental agreement to a country. We then estimate the following regression

$$y^* = \beta_0 + \boldsymbol{x\beta} + e \qquad (1)$$

where $\boldsymbol{x}$ is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters, and error term $\boldsymbol{e}$ is assumed to be independent of $\boldsymbol{x}$ and to have a standard normal distribution. Since we don't observe countries' valuation of the MEA, we define an indicator variable which is equal to unity if a country pair has entered into an MEA. We expect countries to form MEAs if the value of the MEA is positive and not to enter into MEAs without benefits. We therefore define the variable $MEA = 1$ if $y^*>0$ and zero otherwise. We therefore estimate a binary choice model of the following form:

$$P(MEA = 1 \mid X) = G(\beta_0 + \boldsymbol{x\beta}) \qquad (2)$$

where $G(\cdot)$ is the standard normal cumulative distribution function, which ensures that $P(MEA = 1 \mid X)$ lies between 0 and 1. As we noted above, MEA is a binary variable which is unity if two countries jointly participate in an environmental agreement and zero otherwise.

The econometric framework used in the second method is the linear regression model which is shown in equation (3). The dependent variable $\boldsymbol{y}$ measures the number of environmental treaties that both countries have ratified, while the independent variables are the same as those in equation (1).

$$y = \beta_0 + \boldsymbol{x\beta} + e \qquad (3)$$

This specification allows us to examine the degree of environmental collaboration between countries instead of only examining if *any* collaboration exists as in the probit model. For example, France and Germany entered into the first MEA in 1880 but have subsequently signed 301 more MEAs by 2000, whereas Thailand and Vietnam first entered into an MEA in 1950 but have only entered into 47 more by 2000.

For both dependent variables, we can divide our explanatory variables into several groups: gravity variables, economic integration variables, and common resource variables. For gravity variables, we include: (1) SUM OF GDP: the sum of the logarithm of real GDPs of the two countries; (2) DIFFERENCE IN GDP: the absolute value of the difference between the logarithm of real GDPs of the two countries; (3) DISTANCE: the logarithm of the distance between the two countries; and (4) COMMON LANGUAGE: a dummy variable which is unity if the two countries have the same official language. For variables measuring the sum and difference of the logarithm of real GDPs we want to measure whether economically larger countries or countries with similar economic size are more likely to join multilateral environmental treaties together. After controlling for other variables such as distance and having a common border, economically larger countries might have more economic interactions with each other. If cooperation in environmental areas fosters cooperation in other economic areas, then larger countries might be more willing to participate in an environmental agreement together. The variable distance measures the logarithm of distance in kilometers between the two countries. Closer countries might know each other better than remote ones because there might be more economic or non-economic interactions between them. This might foster better cooperation in the environmental arena as well. With the common language variable we want to test whether countries that share the same official language are more likely to have an environmental treaty.

For economic integration variables, we include: (5) SUM OF IMPORTS: the sum of the logarithm of bilateral trade flows of two countries; and (6) TRADE AGREEMENT: a dummy variable which is unity if two countries have a preferential trade agreement. We use these two variables to measure countries' economic integration levels. We expect that countries with a higher level of economic integration will be more likely to cooperate on solving transboundary environmental issues. In addition, when countries ratify trade agreements, they not only decrease tariffs but also increase cooperation in other areas, like the protection of the environment. Trade policy negotiations have been increasingly accompanied by environmental policy measures (Baghdadi, 2013). So we might expect countries with trade agreements are more likely to have environmental agreements with each other.

For common resources variables, we include: (7) BORDER LENGTH: equal to logarithm of (1+length of common border of two countries); (8) SAME REGION: a dummy variable equal to one if the two countries are in the same geographic region; and (9) NEIGHBOR REGION: a dummy variable equal to one if the two countries are located in neighboring geographic regions. Since the MEAs with a few signatories are primarily used to resolve regional environmental issues, controlling for these variables helps better identify the effects of economic factors on countries' MEA cooperation.

We estimate cross-section regressions annually from 1980 to 2000. As mentioned above, countries' cooperation on international environmental issues might foster their economic exchange such as asset cross-holdings and might also impede their bilateral trade flows. To deal with this potential endogeneity issue, we use the 1970 data on GDP variables, bilateral trade flows, and trade agreement dummy.

2.4 Data

Multilateral environmental agreement data are from Ronald Mitchell's International Environmental Agreement Database Project (2002-2015). Basic information on multilateral environmental agreements includes subject or topic of the agreement, its beginning date, and membership. Treaties are categorized into eight subjects: energy, freshwater resources, habitat, nature, oceans, weapons and environment, pollution, and species. In addition, agreements dealing with pollution are further divided into four categories: pollution related to air, land, ocean, and waste. Agreements dealing with species are also divided into four categories: agriculture, birds, fish, and mammals. Member countries and the date when those members ratified the agreement are identified in the database.

There are 1,119 agreements, including original agreements, protocols and amendments, from 1950 to 2012. Countries generally use original agreements to reach major new environmental objectives, use protocols for new but related environmental goals, and use amendments for minor modifications to those existing agreements. While one could exclude those modifications, this will understate the number of significant multilateral environmental agreements (Mitchell, 2003). Indeed, there are a number of important protocols and amendments in our data set, such as the Montreal Protocol on Substances that Deplete the Ozone Layer, Kyoto Protocol to the United Nations Framework Convention on Climate Change, and the amendment to the International Convention for the Regulation of Whaling. On the other hand, including all modifications might include some minor, noncontroversial, or technical amendments (Mitchell, 2003). In our paper, we use the broad definition and do not distinguish between these three types of agreements.

Bilateral trade flow data are aggregated from 4-digit SITC UN Comtrade data. Gravity data are from the CEPII gravity database. Economic integration agreement data are from Baier and Bergstrand (2007). Data for the length of common border come from Wikipedia.

2.5 Results

We begin by comparing the results using MEAs with fewer than the median number of signatories (26), MEAs with greater than the 3rd quartile number of signatories (68), and all MEAs respectively for the year 1990. This gives us a general idea about how economic factors affect countries' cooperation on various agreements in a given year. We then proceed estimate our specifications annually from 1980 to 2000 and plot the coefficients of each explanatory variable over time first using small agreements, followed by large agreements and all agreements.

Previewing our results, economic size, distance, and economic integration variables can successfully explain countries' cooperation on MEAs with fewer than 26 signatories, the median number. These factors have mixed effects in different years for MEAs with more than 68 signatories, the 3rd quartile of signatories and for all MEAs.

2.5.1 Economic determinants of small MEAs, large MEAs, and all MEAs for year 1990

In Table 2.1, we present the marginal effects for the likelihood of two countries having an environmental agreement in 1990. Our dependent variable here is dichotomous and is equal to one if two countries have an environmental agreement in a given year and zero otherwise. In addition, we report marginal effects evaluated at means of independent variables on the probabilities of two countries having an environmental agreement.

Table 2.1 The likelihood of two countries having an MEA

VARIABLES	(1) small agreements	(2) large agreements	(3) all agreements
SUM OF GDP	0.0252***	-0.00303***	-0.00354***
	(0.00129)	(0.000987)	(0.000892)
DIFFERENCE IN GDP	-0.0136***	0.000835	0.000326
	(0.00185)	(0.00135)	(0.00117)
SUM OF IMPORT	0.00294***	0.00447***	0.00352***
	(0.000292)	(0.000324)	(0.000290)
DISTANCE	-0.0570***	-0.00470	-0.0152***
	(0.00622)	(0.00550)	(0.00485)
BORDER LENGTH	0.00695**	0.00389	0.00231
	(0.00310)	(0.00407)	(0.00416)
COMON LANGUAGE	0.0651***	-0.0244***	-0.0245***
	(0.00737)	(0.00672)	(0.00590)
SAME REGION	0.198***	0.00311	0.0165*
	(0.0117)	(0.0103)	(0.00948)
NEIGHBOR REGION	0.103***	0.0132	-0.00586
	(0.0105)	(0.0102)	(0.00852)
TRADE AGREEMENT	0.0473***	0.106***	0.0958***
	(0.0145)	(0.0329)	(0.0364)
Observations	9,216	9,216	9,216

(1) Standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1
(2) All results we present are marginal effects. We use 1970 data on GDP, trade flows, and trade agreements and run regressions for 1990

The first column refers to the results using MEAs with fewer than 26 signatories, the median number. For economic size variables, the sum of logged GDPs has a positive effect indicating that economically large countries are more likely to have a small MEA. If we increase the product of two countries' real GDPs by 10% (since the independent variable is the sum of the logged GDPs), the probability of them having an environmental agreement increases by about 0.2%. This effect becomes more evident if we compare across country pairs. For example, in 1990, the product of France and Germany's real GDPs is about 4400 times of that of Vietnam and Thailand's. This increases the former pair of countries' probability of having an MEA by about 21% compared with the latter pair holding other things equal. The difference in logged GDPs has a negative effect indicating that countries with similar economic sizes are more likely to have a small MEA.

Countries trading more with each other are more likely to have an agreement with a small number of signatories. The marginal effect is significant and positive. As mentioned above, trade agreements do not just eliminate trade barriers, they may also foster countries' environmental cooperation.[1] Our results support this assertion. Countries with a trade agreement are more likely to have an environmental agreement. In 1990 trade agreements tend to increase the probability of two countries having an environmental agreement by about 5%.

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[1] For example, when signing the North American Free Trade Agreement, Canada, Mexico, and the U.S. also signed a side agreement, the North American Agreement on Environmental Cooperation which stipulated that each country must enforce its environmental laws and created a dispute settlement mechanism for enforcement purposes.

If two countries are close to each other, they are more likely to have an agreement. This result is reasonable because MEAs with a few signatories often deal with regional environmental issues and only nearby countries need to cooperate. In addition, since closer countries might know each other better than remote ones, they are more likely to cooperate on environmental issues. Similarly, countries sharing a longer common border, located within the same region as well as neighboring regions are more likely to have such an agreement. Countries with a longer common border may share more common resources together, making them more likely to work together on solving transboundary environmental problems. In addition, countries with the same common official language are also more likely to have an agreement. Results in the first column indicate that economic size, distance, and economic integration variables contribute to countries' cooperation on MEAs with a few signatories.

The second and third columns in Table 2.1 present the results using MEAs with a large number of signatories (68 to be precise) and all MEAs respectively. As we argued above, the results using large agreements and all agreements may be inconclusive. Large environmental agreements often have small effects. In addition, some large agreements are signed by almost every country in the world but have no specific binding targets. If there are few economic costs to joining a large agreement, every country will do that. This kind of cooperation may lack economic driving forces. As a result, our economic determinants may not work well in explaining countries' cooperation on large MEAs.

As we expect, in column 2, most of our variables of interest have no statistically significant effects or have counter intuitive effects like the sum of logged GDPs. The only exceptions are economic integration variables. Countries with trade agreements or those having larger bilateral trade flows are more likely to be parties to a large agreement which likely speaks to the fact that more open economies are more likely to cooperate on environmental issues. Similar results are also shown in column 3 in which we examine all agreements.

We show our results on factors influencing the number of MEAs two countries have in 1990 in Table 2.2. Similar to Table 2.1, we present the results using MEAs with a few signatories, MEAs with many signatories, and all MEAs from column 1 to 3.

Table 2.2 The number of MEAs two countries have

	(1)	(2)	(3)
VARIABLES	small agreements	large agreements	all agreements
SUM OF GDP	0.121***	1.567***	2.185***
	(0.00887)	(0.0777)	(0.0916)
DIFFERENCE IN GDP	-0.0978***	-0.243**	-0.663***
	(0.00914)	(0.102)	(0.115)
SUM OF IMPORT	0.0367***	0.370***	0.531***
	(0.00281)	(0.0207)	(0.0267)
DISTANCE	-0.342***	1.625***	-1.052***
	(0.0522)	(0.273)	(0.372)
BORDER LENGTH	0.268***	0.0739	-0.0365
	(0.0616)	(0.228)	(0.358)
COMON LANGUAGE	0.0330	-1.163***	-2.722***
	(0.0576)	(0.360)	(0.470)
SAME REGION	1.186***	4.585***	8.851***
	(0.0932)	(0.535)	(0.784)
NEIGHBOR REGION	-0.148**	1.718***	3.312***
	(0.0711)	(0.515)	(0.664)
TRADE AGREEMENT	1.605***	4.418***	10.37***
	(0.277)	(1.172)	(1.866)
Observations	9,216	9,216	9,216

(1) Standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1
(2) We use 1970 data on GDP, trade flows, and trade agreements and run regressions for 1990

For small MEAs, economic size, distance, and economic integration variables have similar effects in explaining the number of agreements two countries have as they do in explaining the likelihood of two countries having an agreement. Specifically, economically large countries and those with similar economic sizes, those close to each other, and those with trade agreements and having larger bilateral trade flows tend to have more environmental agreements with a few signatories.

For large MEAs, most of our variables of interest work well in explaining the number of MEAs. The reasons are as follows. In probit estimation two countries with one hundred environmental agreements are treated the same as those having only one environmental agreement. There are some large environmental agreements that most countries in the world have ratified. Many countries join such agreements because they do not need to bear many or any costs as these agreements do not have binding commitments. This may bias our results since we treat as equal country pairs which cooperate a lot and those that cooperate much less. We solve this problem by focusing on small agreements only. In OLS estimation, we compare the number of environmental agreements two countries have. To some extent, this may alleviate some problems caused by large treaties that include almost every country. However, there are some systematic differences between large environmental agreements and small ones. A better way to minimize the bias is to treat these two types of agreements separately in estimation.

2.5.2 Economic determinants of small MEAs, large MEAs, and all MEAs from 1980 to 2000

Figure 2 present the results on economic determinants of the likelihood of two countries having a small environmental agreement. Figure 3 show the results on the determinants of the number of agreements two countries have.

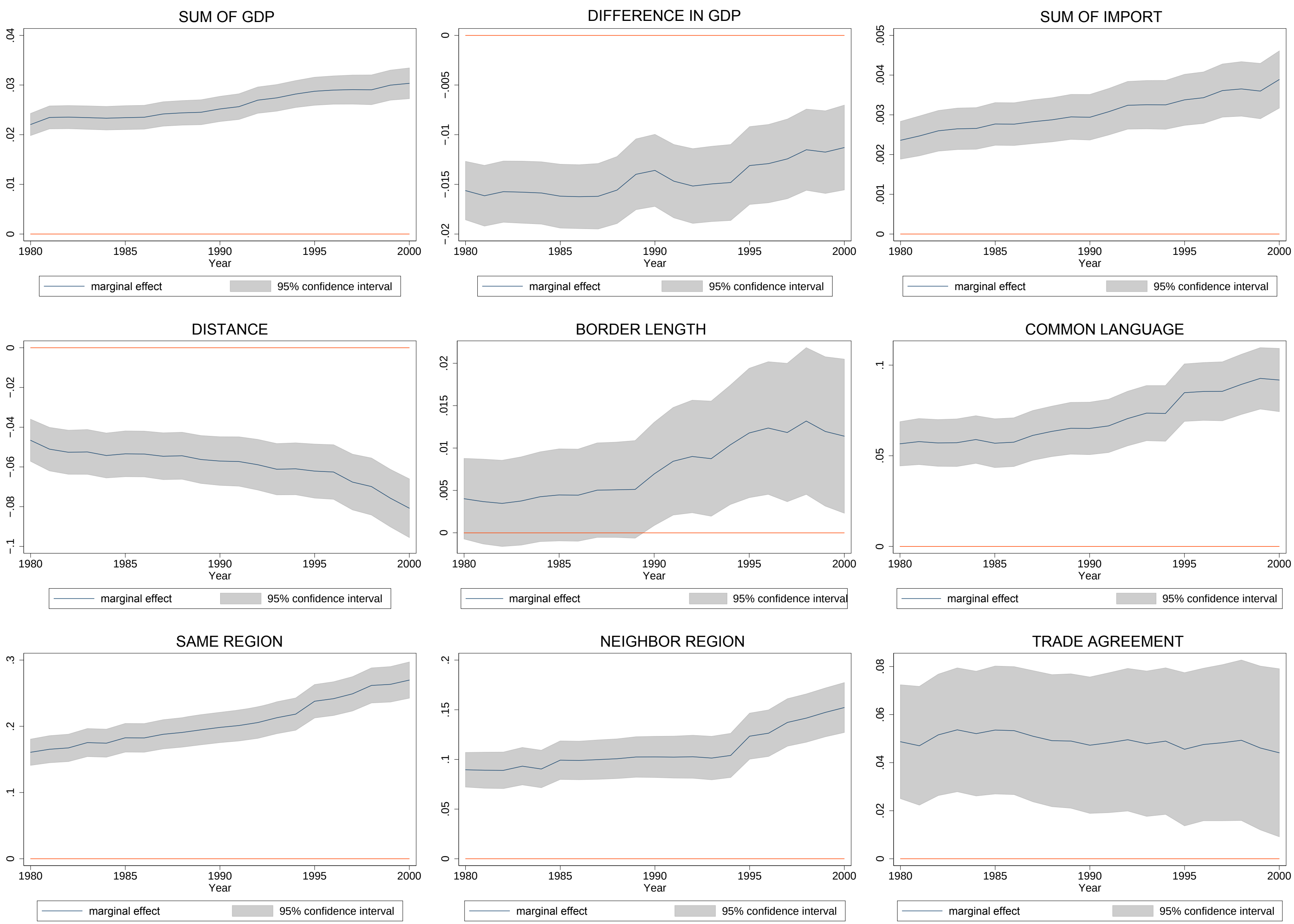


Figure 2.2 Probit results using MEAs with fewer than the median number of signatories

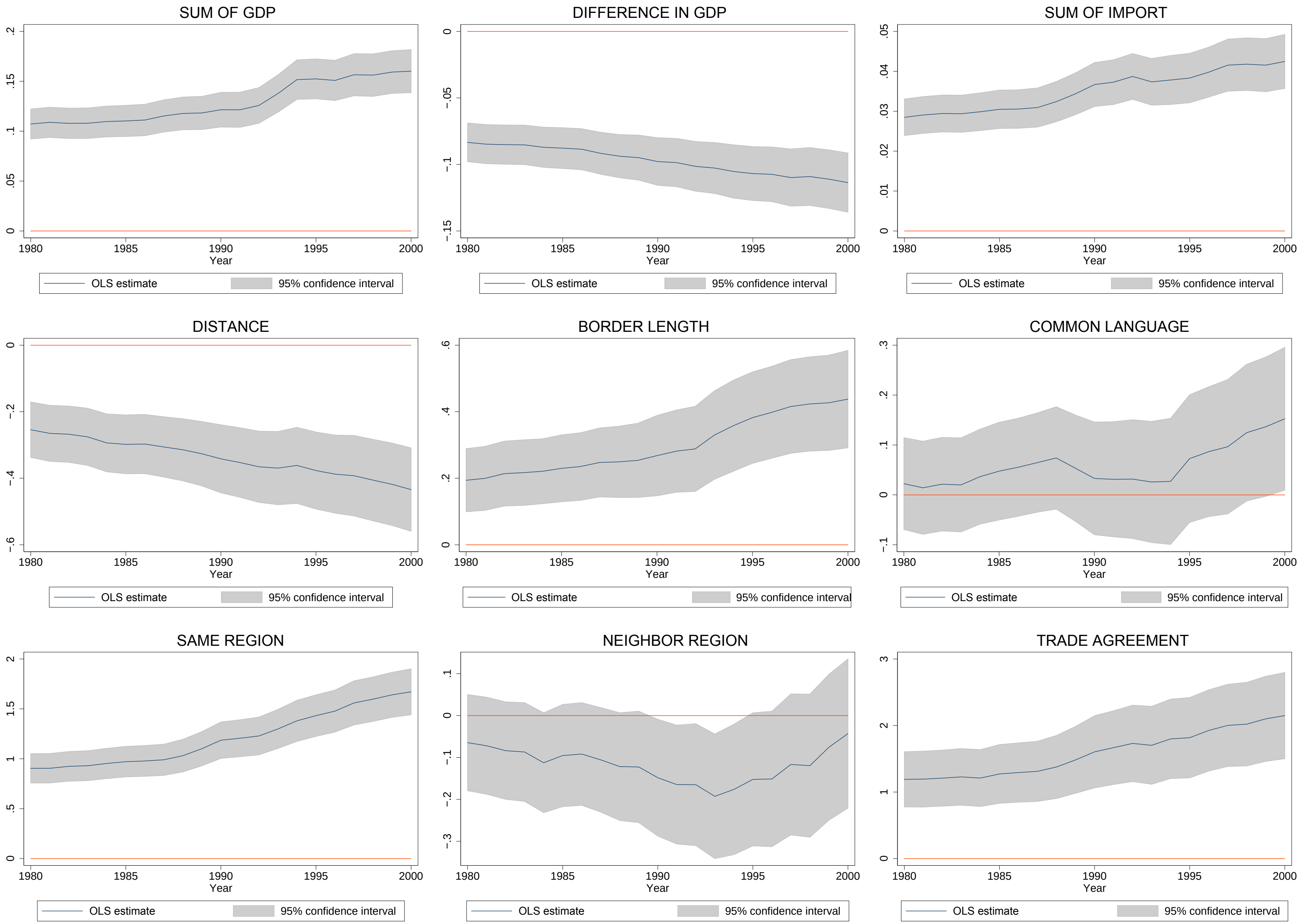


Figure 2.3 OLS results using MEAs with fewer than the median number of signatories

In Figure 2.2, we plot the marginal effect and a 95% confidence interval of each explanatory variable year by year from 1980 to 2000. We use the 1970 data on GDPs, trade flows, and trade agreement variables in each of our estimations. Compared to the results shown in the first column in Table 1, these graphs examine the temporal stability of each determinant. As we can see, the effects of most explanatory variables are rather stable over time. Our results show that two countries are more likely to have an environmental agreement with a few signatories if they are economically large and are of similar economic size, if they are close in distance, if they have a trade agreement, and if their bilateral trade flows are large. These effects are statistically significant over time.

In Figure 2.3, we plot similar graphs on factors determining the number of environmental agreements two countries have. Most determinants have statistically significant and consistent effects over time. Our results show that economic size, bilateral distance, and economic integration variables have similar effects on the number of environmental agreements as they do on the likelihood of having an agreement.

We then investigate countries' cooperation on MEAs with more than 68 signatories and all MEAs in our sample. Figure 2.4 presents the results on the probability two countries having an agreement with a large number of signatories. Economic size variables have mixed effects over time. The sum of logged GDPs has a positive effect in the early 1980s and after 1992 but has a negative effect in other years. The difference in logged GDPs also has mixed results over time and the estimates are statistically insignificantly different from zero in most years. Distance has a negative effect over time with the effect insignificant in early years. Trade agreements and bilateral trade have significantly positive effects over time.

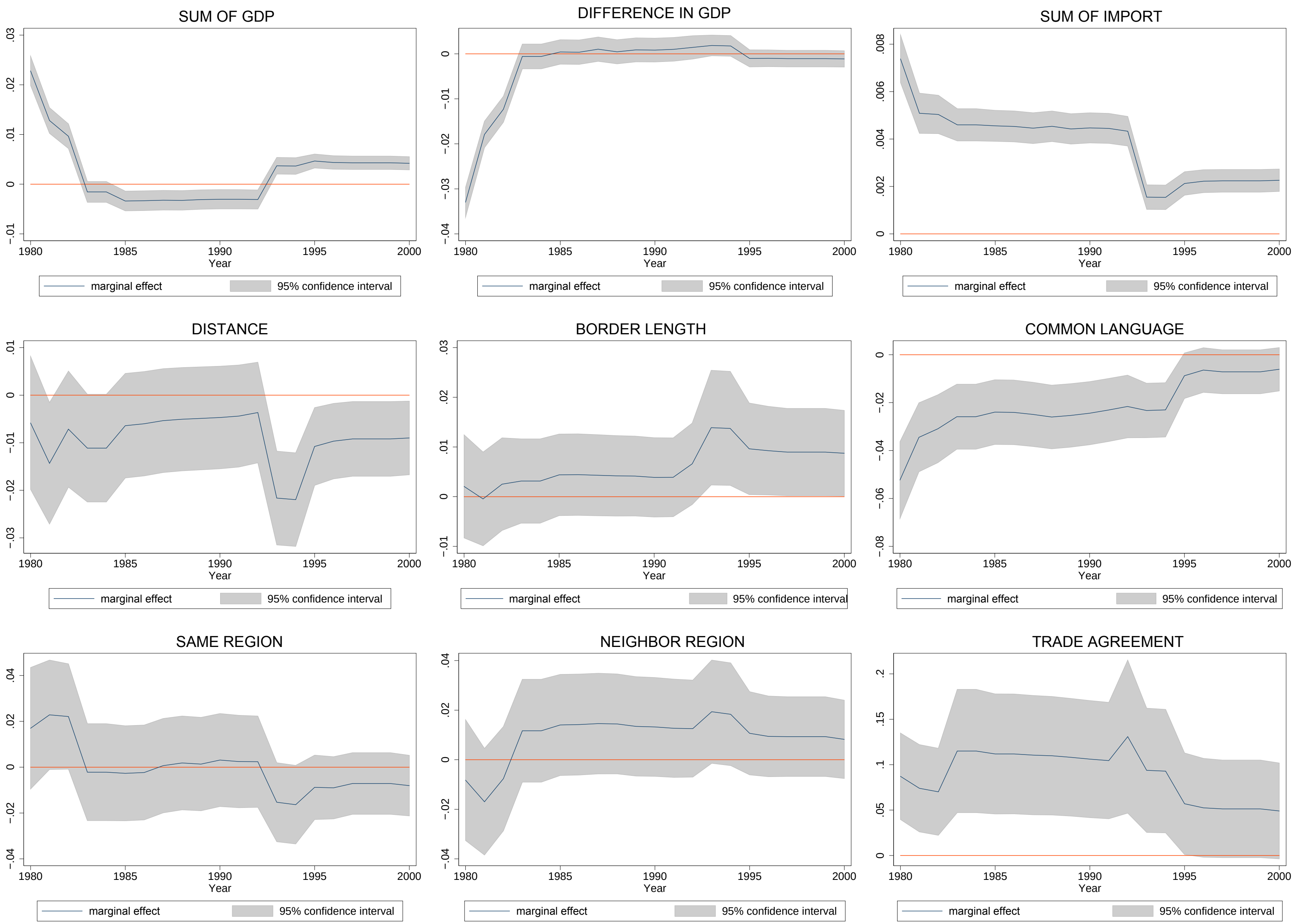


Figure 2.4 Probit results using MEAs with greater than the 3rd quartile number of signatories

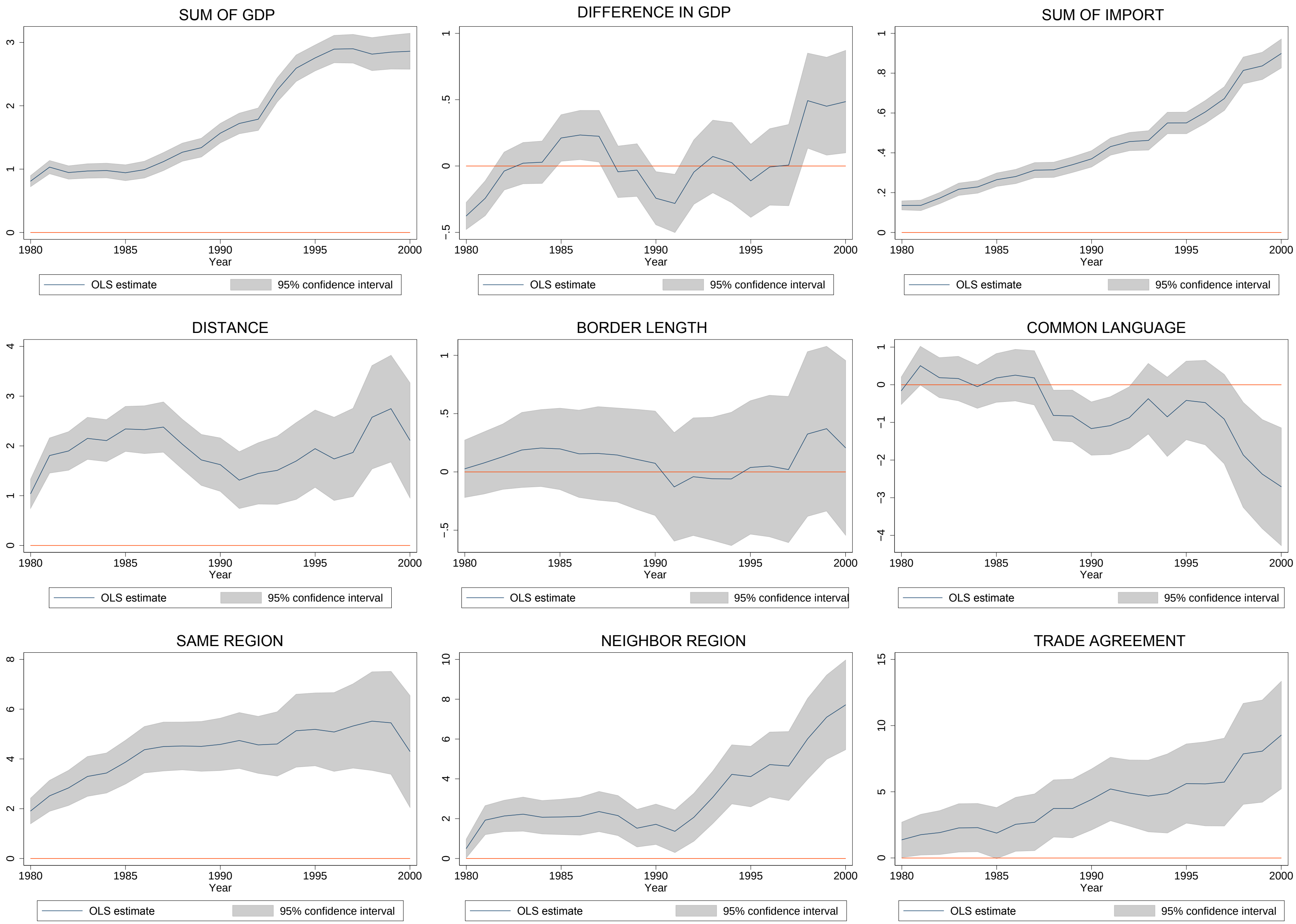


Figure 2.5 OLS results using MEAs with greater than the 3rd quartile number of signatories

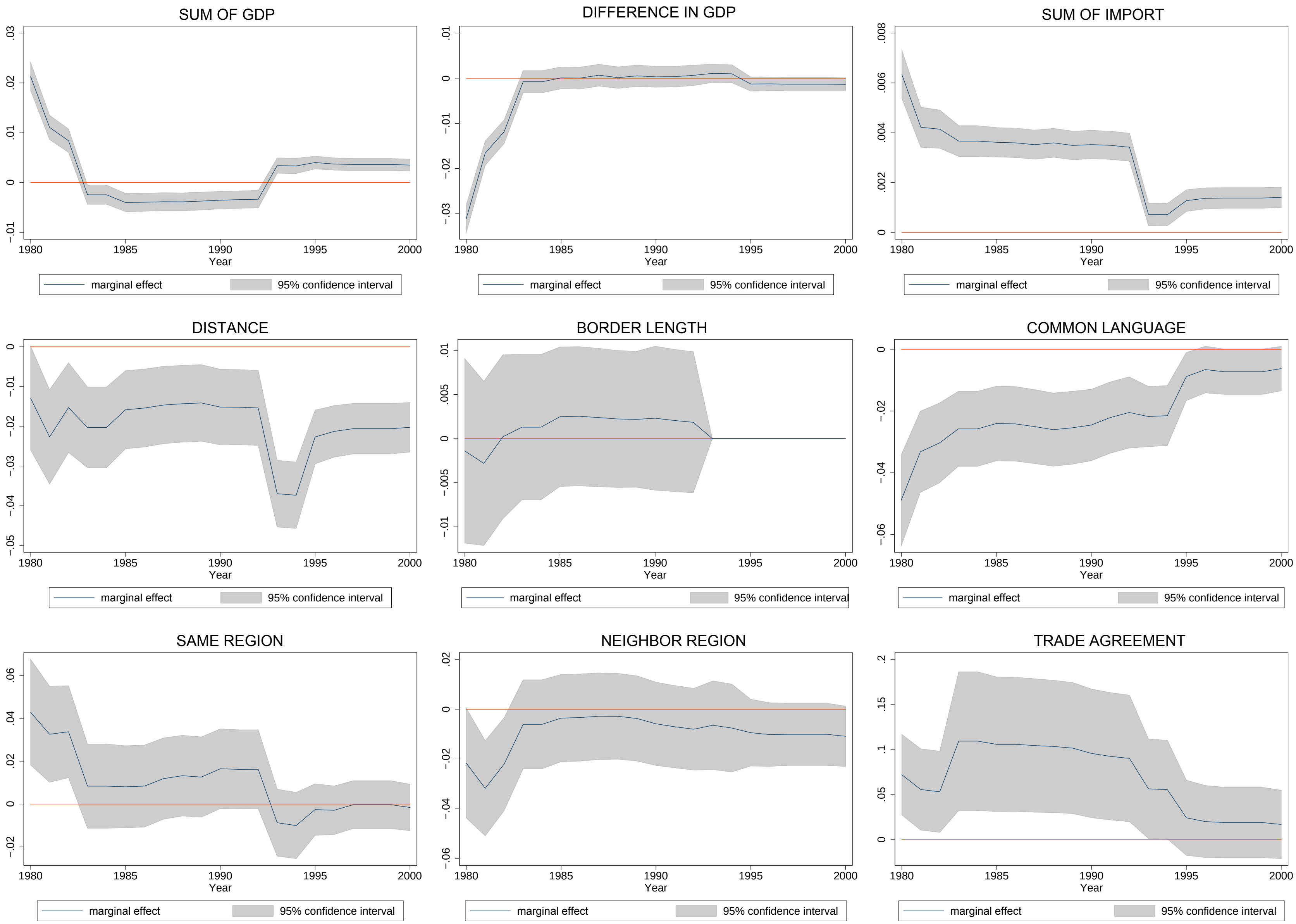


Figure 2.6 Probit results using all MEAs

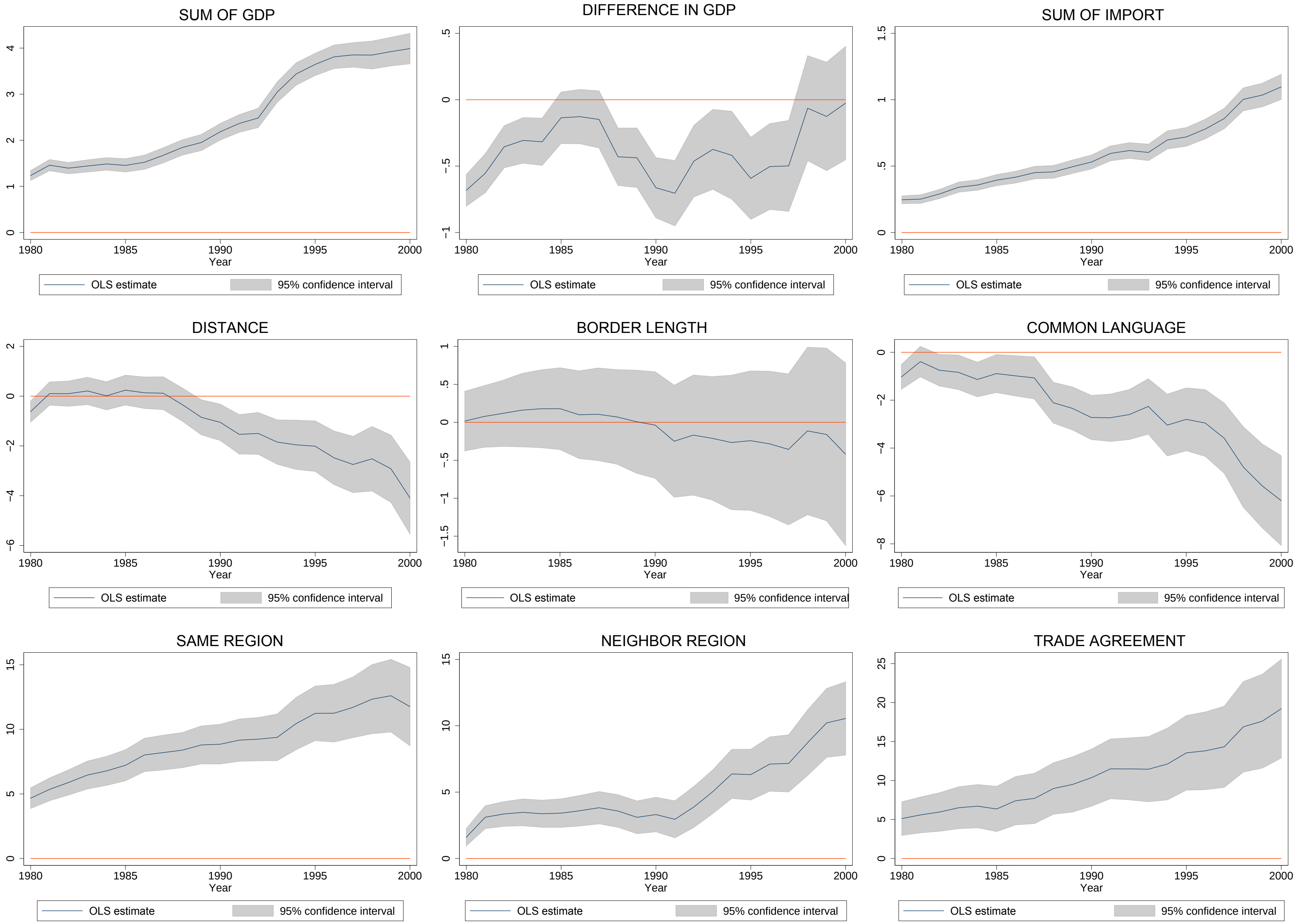


Figure 2.7 OLS results using all MEAs

Figure 2.5 presents the results on the number of MEAs two countries have using agreements with many signatories. The difference in logged GDPs has a mixed effect over time and the coefficient is not significant in many years. Distance has a positive significant effect over time which means that close countries have fewer large environmental agreements than remote ones. This is not at all surprising since in agreements with many signatories, many bilateral pairs of countries will be far apart. The sum of logged GDPs, existence of a trade agreement, and bilateral trade flow all have positive and statistically significant effects over time.

Figures 2.6 and 2.7 show our results for the likelihood of two countries having an agreement and the number of agreements two countries have respectively for all MEAs in our sample. These results show how our independent variables work if we do not separate the small agreements from the large agreements. Similar to the results for large agreements, economic factors perform poorly in explaining the likelihood of two countries having an MEA. On the other hand, economic size, distance, and economic integration variables work well in the OLS regression which examines the number of MEAs two countries have.

2.6 Robustness

We implement several robustness tests to check the sensitivity of our results. We first examine various alternative specifications in Table 2.3.We only use small agreements which are most interesting and repeat our regressions for year 1990. Then in Figure 2.8 and 2.9 we extend our results for a longer period from 1965 to 2000 and see how our explanatory variables work in early years.

In Table 2.3, we present our results using alternative specifications. As before, we use 1970 data on GDPs, trade flows, and trade agreement variables. There are two panels in this table. Panel A (from column 1 to column 4) examines the likelihood of two countries having an environmental agreement. Panel B (from column 5 to column 10) examines the number of environmental agreements two countries have. For the first panel, column 1 is the baseline result which is the same as the first column in Table 1. In column 2, we exclude all potential endogenous variables and use only geographic ones. These variables have similar effects with those in column 1. In column 3, we exclude trade agreement and trade flow variables and in column 4 we only exclude trade flows. This accounts for the potential concerns that gravity variables may affect countries' participation in preferential trade agreements and bilateral trade flows. As we can see, estimates in columns 3 and 4 have similar signs and magnitudes with those in the baseline result. For the second panel, column 5 presents the baseline result which is the same as the first column in Table 2. In the following three columns, we estimate OLS models using similar specifications as those from columns 2 to 4. Our estimates are similar to the baseline result. In columns 9 and 10, we employ Poisson and negative binomial estimators to deal with the count nature of our dependent variables. All explanatory variables still have similar effects.

In Figures 2.8 and 2.9, we present the probit results and OLS results from 1965 to 2000 using MEAs with less than the median number of signatories and employing our benchmark specifications given by equations (1) and (3). To obtain results in early years (before 1980), we have to use explanatory variables in their current-year values since information on GDP and trade flows is missing for many of the earlier years. We compare the results from using current-year values to those using 1970 values by plotting both sets of coefficients in the same figure. Most variables have similar effects when we use their current-year values in estimation. As we can see, most variables of interest have similar effects in the early years.

Table 3 Alternative Specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Panel A: The likelihood of having an MEA				Panel B: The number of MEAs two countries have					
VARIABLES	Baseline results	No GDP, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline results	No GDP, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Poisson	Negative binomial
SUM OF GDP	0.0252***		0.0296***	0.0324***	0.121***		0.196***	0.199***	0.247***	0.301***
	(0.00129)		(0.00102)	(0.00116)	(0.00887)		(0.0110)	(0.0115)	(0.0123)	(0.0118)
DIFFERENCE IN GDP	-0.0136***		-0.0108***	-0.0133***	-0.0978***		-0.0746***	-0.0967***	-0.124***	-0.157***
	(0.00185)		(0.00161)	(0.00184)	(0.00914)		(0.00770)	(0.00919)	(0.0179)	(0.0216)
SUM OF IMPORT	0.00294***				0.0367***				0.0281***	0.0330***
	(0.000292)				(0.00281)				(0.00238)	(0.00302)
DISTANCE	-0.0570***	-0.0341***	-0.0654***	-0.0652***	-0.342***	-0.259***	-0.491***	-0.436***	-0.330***	-0.637***
	(0.00622)	(0.00258)	(0.00554)	(0.00626)	(0.0522)	(0.0261)	(0.0536)	(0.0551)	(0.0515)	(0.0703)
BORDER LENGTH	0.00695**	0.0101***	0.00557**	0.00542*	0.268***	0.329***	0.309***	0.257***	-0.0104	0.00579
	(0.00310)	(0.00144)	(0.00280)	(0.00319)	(0.0616)	(0.0506)	(0.0630)	(0.0628)	(0.0159)	(0.0208)
COMON LANGUAGE	0.0651***	0.0372***	0.0697***	0.0712***	0.0330	0.102***	0.212***	0.110*	0.523***	0.739***
	(0.00737)	(0.00324)	(0.00648)	(0.00738)	(0.0576)	(0.0268)	(0.0504)	(0.0572)	(0.0772)	(0.0718)
SAME REGION	0.198***	0.0825***	0.174***	0.198***	1.186***	0.664***	1.207***	1.185***	1.417***	1.473***
	(0.0117)	(0.00509)	(0.0106)	(0.0118)	(0.0932)	(0.0531)	(0.0978)	(0.0969)	(0.104)	(0.127)
NEIGHBOR REGION	0.103***	0.0446***	0.0757***	0.0958***	-0.148**	-0.138***	-0.355***	-0.221***	0.499***	0.456***
	(0.0105)	(0.00474)	(0.00938)	(0.0106)	(0.0711)	(0.0356)	(0.0736)	(0.0735)	(0.0955)	(0.118)
TRADE AGREEMENT	0.0473***			0.0676***	1.605***			1.862***	0.186**	0.234*
	(0.0145)			(0.0142)	(0.277)			(0.285)	(0.0887)	(0.129)
Observations	9,216	22,791	10,153	9,216	9,216	22,791	10,153	9,216	9,216	9,216
R-squared					0.316	0.121	0.262	0.291		
ln(\alpha)										0.744***
										(0.0667)

Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1

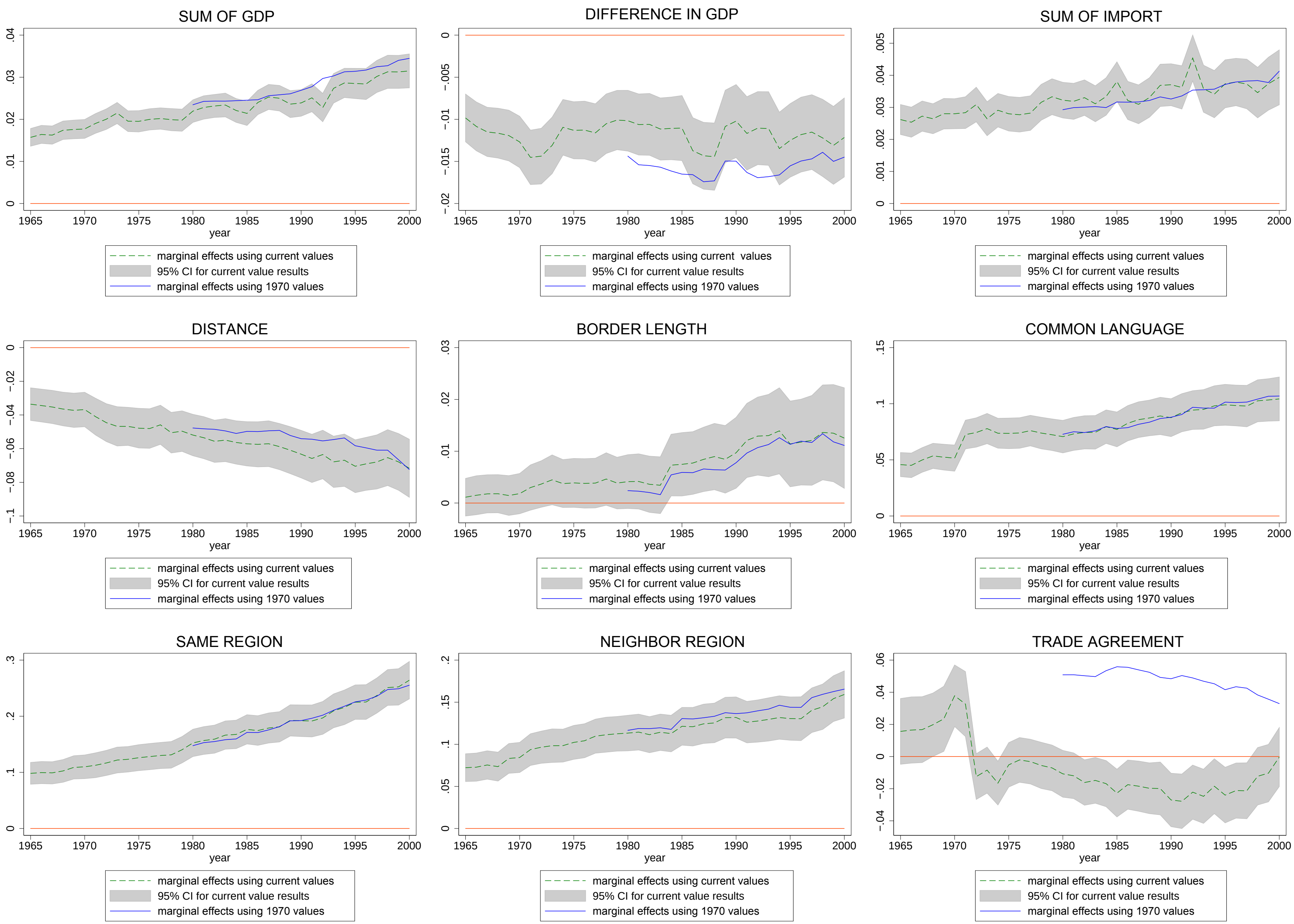


Figure 2.8 Probit results using MEAs with less than the median number of signatories

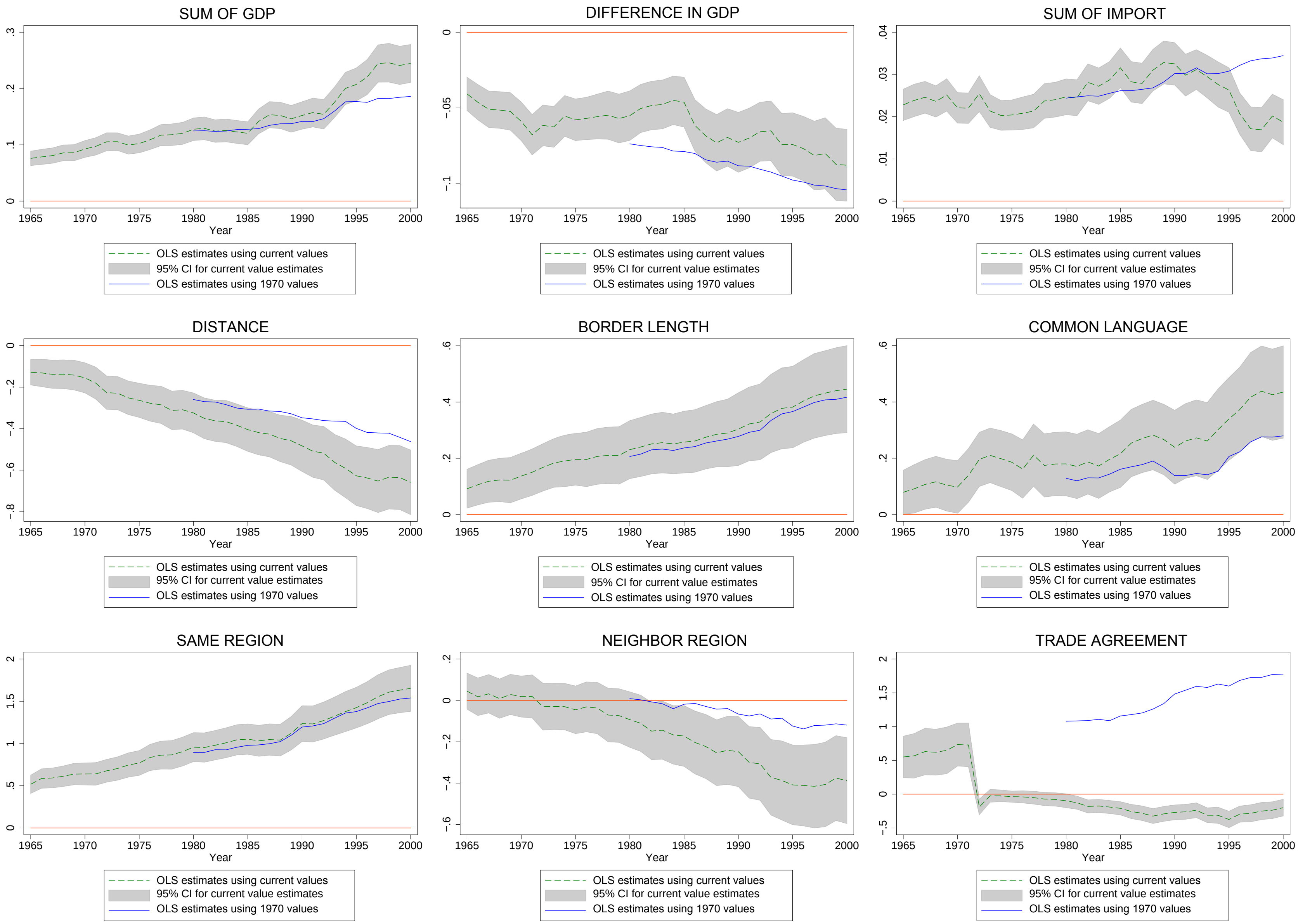


Figure 2.9 OLS results using MEAs with less than the median number of signatories

2.7 Conclusion

In this chapter, we employ a gravity type model to examine the economic factors that determine countries' cooperation on multilateral environmental agreements (MEAs). We separately examine MEAs with fewer than the sample median number of signatories (26), MEAs with greater than the 3rd quartile number of signatories (68), and all the MEAs in the sample. Our approach is motivated by a hypothesis that environmental agreements with a small number of signatories are more likely to be initiated in order to deal with transboundary environmental issues and common pool resource issues. As such, these agreements are more likely to have binding commitments and, as a result, are more likely to be affected by economic determinants. Larger agreements, such as those signed by virtually all countries in the world, may be agreements largely expressing an intent and desire to deal with an issue, but embody no binding commitments for countries which sign them. The determinants of such agreements may not be economic in nature.

Our results show that two countries are more likely to have an MEA or have more MEAs if they: 1) are economically large and of similar economic size, 2) are closer to each other in distance, 3) have a preferential trade agreement, and 4) have larger bilateral trade flows. The results suggest that countries' economic interactions may help them overcome potential free-riding problems to work together on transboundary environmental issues. In addition, since the ratification of MEAs often require countries to impose more stringent environmental standards, extensive economic interactions may also help offset the unfavorable "pollution haven effect".

CHAPTER 3

ECONOMIC DETERMINANTS OF POLLUTION AND RESOURCE AGREEMENTS

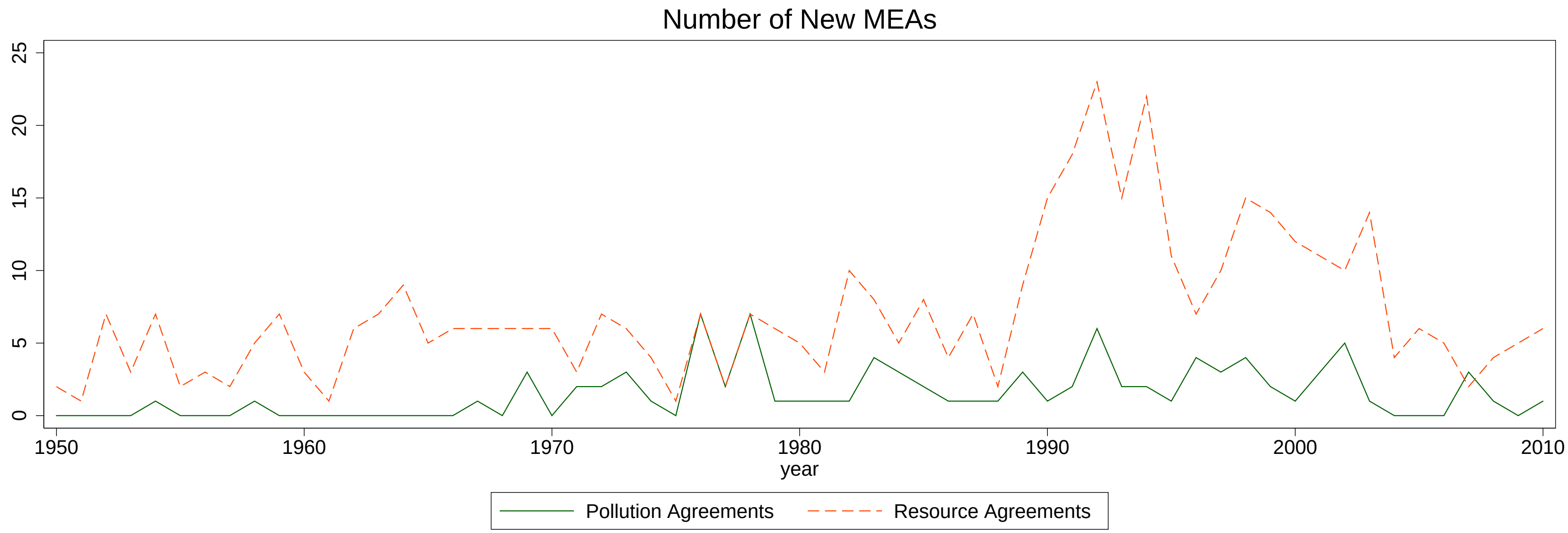
3.1 Introduction

Countries can implement domestic policies to deal with environmental externalities happening within their borders. However, many of the most urgent environmental issues nowadays are international in nature and can only be solved through countries' cooperation. Some examples include climate change, acid rain, loss of biodiversity, and ocean pollution. To address such problems, countries often adopt multilateral environmental agreements (MEAs).

One major problem that prevents countries' collective action on solving international environmental issues is free riding. Theoretical research suggests that a self-enforcing MEA can only support a few signatories and MEAs with a large number of signatory countries can hardly achieve more than what individual countries would do without MEAs (e.g. Barrett, 1994, 1997, 2001; Carraro and Siniscalo, 1993, 1998; Hoel, 1992; Hoel and Schneider, 1997). In spite of such pessimistic views, some empirical papers find that trade openness may contribute to countries' MEA membership (Neumayer, 2002; Egger et al, 2011, 2013). In addition, Sigman (2004) examines the relationship between bilateral trade and transboundary pollution among trading partners. She shows that countries with more extensive trade have lower pollution in rivers they share than other countries. Besedes et al. (2016) examine the economic determinants of countries' cooperation on MEAs and their results suggest that countries having more economic interaction are more likely to cooperate on multilateral environmental agreements.

To distinguish from previous research, we examine the economic determinants of MEAs across different environmental issues. We focus on pollution related agreements and resource related agreements separately. In addition, we examine whether there are any spillover effects between countries' coordination on these two types of agreements. There are several differences between the two types of agreements. First, pollution agreements address various forms of pollution, while resource agreements focus on the conservation or management of natural resources. In line with the classification in Ronald Mitchell's IEA database (2016) pollution related agreements include agreements dealing with air pollution, land pollution, marine pollution, and waste pollution. Resource related agreements include those dealing with natural resource, habitat, freshwater resource, ocean, and species.

Second, the number of resource agreements are much larger than that of pollution ones. In addition, countries' cooperation on international pollution issues is a relatively new phenomenon compared to their cooperation on resource issues. The number of pollution and resource agreements over time is shown in Figure 2.1. The top panel of Figure 1 shows the number of new pollution agreements and resource agreements from 1950 to 2010, and the bottom panel of Figure 2.1 shows the cumulative number of both types of agreements for the same period. As shown in the figures, there are less than 100 pollution agreements in 2000 and the number of resource agreements is almost 5 times of that. In addition, most pollution agreements are adopted after 1970 which indicates that such agreements are a rather new development. We observe a relatively large number of such agreements formed in the late 1970s and from the early 1990s to the early 2000s. On the other side, MEAs dealing with resource issues date back to 1800s and they account for the majority of MEAs before 1970. We also observe a dramatic surge in the number of such agreements from early 1990s to early 2000s. Third, pollution agreements tend to have a larger number of signatories than resource agreements do. The median number of signatories of pollution agreements is 36, while the median of resource agreements is only 10. The reasons stated above make it worthwhile to separately examine the economic determinants of these two types of agreements.



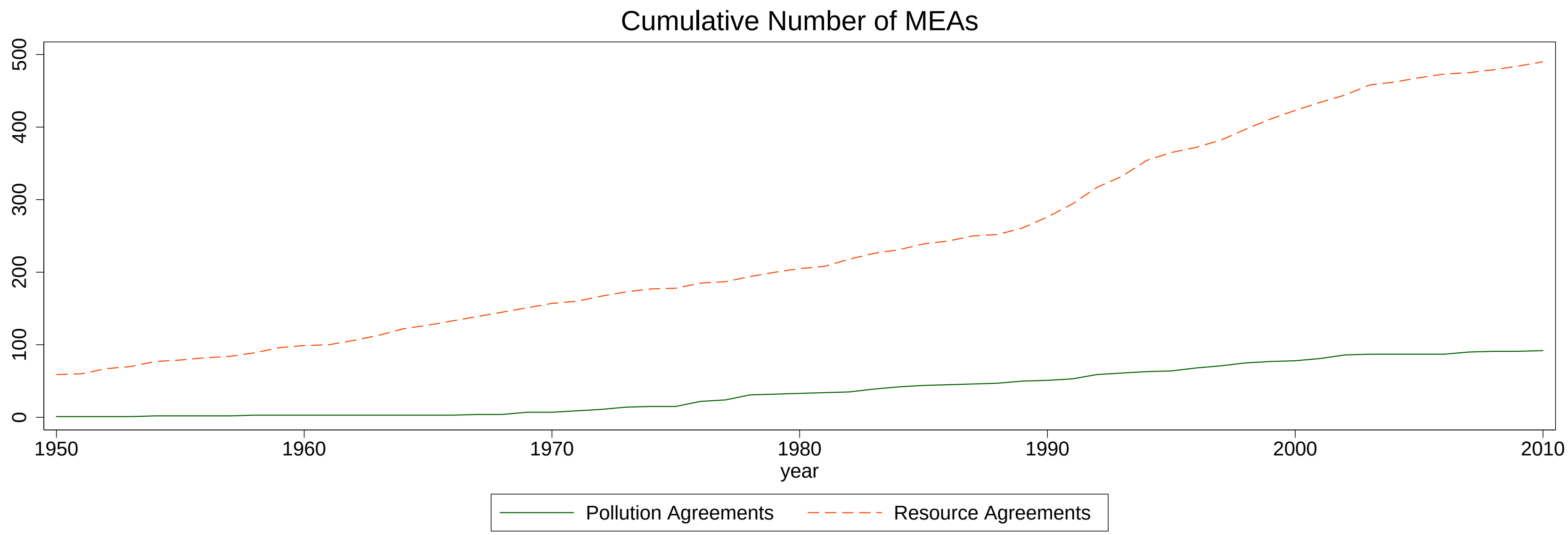


Figure 3.1 Annual Count of Pollution Agreements and Resource Agreements

The agreement in this paper refers to any original agreement or protocol. Countries generally sign agreements to pursue major new policy objectives and employ protocols for new but related policy goals (Mitchell, 2003). For example, countries employ the Convention on Long-Range Transboundary Air Pollution (LRTAP) as well as its eight protocols, such as 1985 Helsinki Protocol on the Reduction of Sulphur Emissions, to deal with transboundary air pollution. We do not include any amendment in our analysis.

We employ four econometric models to explore the economic factors that influence countries' cooperation on pollution agreements and resource agreements. First, we estimate a probit model to examine the likelihood of two countries' cooperation on environmental agreements and we estimate an ordinary least square model to examine the number of agreements two countries have. These models allow us to examine if any environmental collaboration exists between countries as well as the degree of such collaboration. We estimate these models year by year from 1980 to 2000 which allows us to examine how the effects of the economic factors change over time. To deal with potential endogeneity issues, we use 1970 data on GDPs, trade agreements, and bilateral trade flows.

Second, we estimate two linear dynamic panel-data models to examine the number of agreements two countries have following the methods developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) in which the lagged dependent variables are used as explanatory variables. The Arellano-Bond model employs the generalized method of moments (GMM) and uses the lagged levels of the dependent variable and first differences of the exogenous variables as instruments for the first-differenced equation. On the other hand, Arellano–Bover/Blundell–Bond model uses moment conditions in which lagged first differences of the dependent variable are instruments for the level equation as well as the moment conditions used in Arellano-Bond method. We estimate these two models by using the data from 1960 to 2005.

There are 588 MEAs, 92 pollution agreements and 496 resource agreements, among 140 countries in the period from 1960 to 2005. The results show that economic size, distance, and economic integration levels matter for countries' collaboration on both pollution related and resource related agreements. Specifically, we show that two countries are more likely to have an environmental agreement or have more of them if: 1) they are economically larger and of similar economic size, 2) are closer in distance, 3) have a preferential trade agreement, and 4) trade more with each other. The results are most robust for agreements among a relatively small number of countries. In addition, we find evidence that there exist spillover effects between countries' coordination on pollution and resource agreements. Countries with more pollution agreements tend to cooperate on more resource agreements and vice versa.

3.2 Economic Determinants of MEA Cooperation

In this section, we examine three sets of economic factors which may contribute to countries' collaboration on multilateral environmental agreements. Following Besedes et al. (2016), we include gravity variables, common resource variables, and economic integration variables.

As for gravity variables, we include (1) SUM OF GDP: the sum of the logarithm of real GDPs of the two countries; and (2) DIFFERENCE IN GDP: the absolute value of the difference between the logarithm of real GDPs of the two countries. We use these two variables to examine whether economically larger countries or countries with similar size are more likely to cooperate on pollution agreements and resource agreements. Economically larger countries may interact more economically with each other after controlling for other factors. Countries with more economic interactions may have more opportunities for "issue linkage". We also include (3) DISTANCE: the logarithm of the distance between two countries' economic centers; and (4) COMMON LANGUAGE: a dummy variable equal to one if the two countries have the same official language. Closer countries may have more economic exchanges. Furthermore, these countries may also share similar culture or history which may promote their environmental coordination. We collect our GDP, distance, and common language data from the CEPII gravity database.

As for variables which proxy for common resources, we include: (5) BORDER LENGTH: logarithm of (1+length of common border of two countries); (6) SAME REGION: a dummy variable equal to one if the two countries are in the same geographical region; and (7) NEIGHBOR REGION: a dummy variable equal to one if the two countries are located in neighboring geographical regions. We assume that countries with longer common border or within the same region are more likely to share some common resources such as a lake or river basin. These countries may have more opportunities to incur transboundary environmental issues. After controlling for these variables we can better identify the effects of economic factors. Border length data are provided by the CIA World Factbook. The information about geographical regions is provided by United Nations' country grouping. Countries in the world are divided into 13 regions: North America, Caribbean, Central America, South America, Western Europe, Eastern Europe, North Africa, Sub-Saharan Africa, Middle East, South Asia, Central Asia, East Asia, and Oceania.

As for economic integration variables, we include: (8) SUM OF IMPORTS: the sum of the logarithm of bilateral trade flows of two countries; and (9) TRADE AGREEMENT: a dummy variable which is unity if two countries have a preferential trade agreement. We expect that countries are more likely to cooperate on MEAs if they have a higher economic integration level. Bilateral trade flow data are aggregated from 4-digit SITC UN Comtrade data. Data on trade agreements are from the Database on Economic Integration Agreements compiled by Scott Baier and Jeffrey Bergstrand (2007).

3.3 Econometric Models

We employ four econometric models to examine the economic factors that influence countries' cooperation on pollution agreements and resource agreements. Specifically, we estimate a probit model to examine the likelihood of two countries having an agreement. We estimate an ordinary least square model and two linear dynamic panel data models to examine the number of agreements two countries have. We run probit and OLS models for each year from 1980 to 2000 by using cross-sectional data. To explore the dynamic nature of the data, we employ the dynamic panel data models from 1960 to 2005.

The econometric framework used in the first method is the binary choice model. In equation (1), y^* denotes a latent variable which is the utility countries gain from a multilateral environmental agreement (either pollution related or resource related). On the right hand side, $\boldsymbol{x}$ represents a vector of explanatory variables which were introduced in the previous section and $\boldsymbol{\beta}$ a vector of parameters. The error term $\boldsymbol{e}$ is assumed to be independent of $\boldsymbol{x}$ and to have a standard normal distribution.

$$y^* = \beta_0 + \boldsymbol{x\beta} + e. \qquad (1)$$

Since countries' utility gains from an MEA cannot be observed, we introduce an indicator variable, *MEA*, which is equal to one if two countries are both parties to an MEA. We expect countries to form an MEA if the utility they gain from the agreement is positive and not to enter without benefits. We therefore define $MEA = 1$ if $y^* > 0$ and zero otherwise. We then estimate the following binary choice model,

$$P(MEA = 1|\boldsymbol{X}) = G(\beta_0 + \boldsymbol{x\beta}) \qquad (2)$$

where $G(\cdot)$ is the standard normal cumulative distribution function.

The econometric framework used in the second method is the linear regression model as shown in equation (3). The dependent variable y measures the number of pollution related agreements or resource related agreements that both countries have ratified in a certain year, while the independent variables are the same as those in equation (1)

$$y = \beta_0 + \boldsymbol{x\beta} + e. \qquad (3)$$

We estimate the above specifications year by year from 1980 to 2000 allowing us to examine the stability of the determinants over time. However, it is possible that countries' joint membership to environmental agreements may also affect their economic performances such as GDP and bilateral trade flows. Rose and Spiegel (2009) argue countries' joint MEA participation promotes their cross-holdings of assets. On the other hand, Besedes et al. (2016) and Besedes and Wang (2016) show that countries' joint MEA membership has a small negative effect on their bilateral trade flows. To deal with the possible reverse causality issue, we use the 1970 data on GDPs, trade agreement, and trade flows.

To further explore the dynamic structure of our data, we employ several dynamic panel data models. In a certain year, the number of agreements two countries have may influence their environmental cooperation in subsequent years. In other words, the history of countries' cooperation on environmental issues may play a role in their current cooperation. To examine this possibility, we include the lagged dependent variables in the following model,

$$y_{it} = \alpha y_{it-1} + \boldsymbol{x_{it}} \boldsymbol{\beta} + u_i + \epsilon_{it} \tag{4}$$

in which y_{it-1} measures the environmental agreements two countries have in previous year and u_i captures the unobserved country-pair level effect.

We can eliminate u_i by employing first-difference or fixed-effect estimations. However, there is still correlation between the differenced lagged dependent variable and the disturbance term. One way to solve the problem is to use moment conditions in which lags of the dependent variable and first differences of the independent variables are instruments for the first-differenced equation (Arellano and Bond, 1991). A potential weakness of the Arellano–Bond estimator is that lagged levels are often rather poor instruments for first differenced variables, especially when the variables are close to a random walk. Arellano and Bover (1995) and Blundell and Bond (1998) include moment conditions in which lagged differences are instruments for the level equation as well as the moment conditions used in Arellano–Bond estimation. Both of these two methods assume that there is no autocorrelation in the idiosyncratic errors. We will present one-step GMM estimator and two-step GMM estimator by using Arellano–Bond method as well as Arellano and Bover/Blundell and Bond method.

We separately examine the MEAs with a small number of signatories and those with a large number of signatories. Specifically, for pollution agreements, we focus on MEAs with less than 36 signatories (sample median) and those with more than 63 signatories (3^{rd} quartile), while for resource agreements, we examine MEAs with less than 10 signatories (sample median) and those with more than 28 signatories (3^{rd} quartile). This approach is motivated by a hypothesis that environmental agreements (pollution and resource related) with a small number of signatories are more likely to be initiated in order to deal with common pool resource issues. These agreements are more likely to have binding commitments and are more likely to be affected by economic determinants. Large agreements, especially those including almost all the countries in the world, may be agreements only expressing an intent to deal with an issue and may not have binding commitments for its members. Economic factors may not have any effects on such agreements.

Multilateral environmental agreement data come from Ronald Mitchell's International Environmental Agreement Database Project (2016). Basic information on multilateral environmental agreements includes subject or topic of the agreement, its beginning date, and membership. Treaties are categorized into eight subjects: energy, freshwater resources, habitat, nature, oceans, weapons and environment, pollution, and species. In addition, agreements dealing with pollution are further divided into four categories: pollution related to air, land, ocean, and waste. Agreements dealing with species are also divided into four categories: agriculture, birds, fish, and mammals.

Member countries and the date when those members ratified the agreement are identified in the database.

3.4 Results

We first present results for pollution agreements and then for resource agreements. In each category, we begin by comparing the results using MEAs with fewer than the median number of signatories and MEAs with greater than the 3rd quartile number of signatories respectively for the year 2000. This gives us a general idea about how economic factors affect countries' cooperation on various agreements in a given year. We then estimate our specifications annually from 1980 to 2000 and plot the coefficients of each explanatory variable over time to examine how the effect of each factor changes over time. As mentioned before, we use 1970 data on GDPs, trade flows, and trade agreement variable to account for potential endogeneity issues. We then present the results of quantile regressions for the year 2000. After that, we show the dynamic panel data estimates by using data from 1960 to 2005. At last, we show the evidence of spillover effects which indicate that countries' cooperation on one type of agreements may influence their cooperation on other types.

Previewing our results, economic size, distance, and economic integration variables can successfully explain countries' cooperation on both pollution related agreements and resource related agreements. These effects are most robust for the agreements with a small number of signatories.

3.4.1 Economic Determinants of Pollution Related Agreements

Table 3.1 presents the probit and OLS results using pollution MEAs with less than 36 (the median) signatories for the year 2000. Panel 1 (the first four columns) shows the marginal effects for the likelihood of two countries having a pollution agreement. The dependent variable is a dummy equal to one if two countries have an MEA in 2000 and zero otherwise.

We exclude GDPs and trade related variables and focus mainly on geographic variables in column one. We include GDP variables in column 2 and then include trade agreement and trade values in column 3 and 4 respectively. For column one, distance has a negative effect indicating that closer countries are more likely to have a pollution related agreement. As we argued before, closer countries may have more economic interactions with each other and they may also share similar cultural backgrounds which may facilitate their cooperation. In addition, the pollution agreements with a small number of countries may mainly deal with regional environmental issues which only those close countries are interested in. Similarly, the same region dummy also has a positive and significant effect. The length of border has a positive but insignificant effect. Common official language has a negative effect which means that countries with the same official language are less likely to have a pollution agreement. Most countries where English is the official language are former British Colonies. These countries are

Table 3.1 Results for pollution agreements with fewer than the sample median number of signatories

	1	2	3	4	5	6	7	8	9	10
	Panel 1 The likelihood of having an MEA				Panel 2 The number of MEAs two countries have					
VARIABLES	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	Poisson	Negative Binomial
SUM OF GDP		0.0144***	0.0144***	0.0121***		0.0638***	0.0580***	0.0326***	0.241***	0.303***
		(0.000692)	(0.000696)	(0.000729)		(0.00395)	(0.00367)	(0.00280)	(0.0171)	(0.0165)
DIFFERENCE IN GDP		0.000949	0.000911	0.000827		-0.0147***	-0.0195***	-0.0199***	-0.00797	-0.00336
		(0.000999)	(0.00101)	(0.000996)		(0.00324)	(0.00351)	(0.00350)	(0.0259)	(0.0243)
SUM OF IMPORTS				0.000873***				0.0119***	0.0320***	0.0293***
				(0.000154)				(0.00119)	(0.00390)	(0.00335)
DISTANCE	-0.0479***	-0.0283***	-0.0282***	-0.0252***	-0.241***	-0.201***	-0.173***	-0.142***	-0.532***	-0.628***
	(0.00387)	(0.00312)	(0.00314)	(0.00308)	(0.0228)	(0.0203)	(0.0193)	(0.0185)	(0.0672)	(0.0678)
BORDER LENGTH	0.00206	-0.00208	-0.00216*	-0.00163	0.0252	0.00795	-0.00637	-0.00260	-0.0711***	-0.0743***
	(0.00202)	(0.00129)	(0.00130)	(0.00129)	(0.0245)	(0.0235)	(0.0226)	(0.0223)	(0.0227)	(0.0272)
COMMON LANGUAGE	-0.0315***	0.00280	0.00238	0.000708	-0.188***	-0.0925***	-0.138***	-0.163***	-0.381***	-0.159
	(0.00674)	(0.00468)	(0.00478)	(0.00471)	(0.0222)	(0.0185)	(0.0213)	(0.0223)	(0.114)	(0.115)
SAME REGION	0.0260***	0.0381***	0.0377***	0.0372***	0.366***	0.465***	0.446***	0.447***	1.708***	1.534***
	(0.00737)	(0.00580)	(0.00577)	(0.00570)	(0.0443)	(0.0462)	(0.0443)	(0.0433)	(0.126)	(0.130)
NEIGHBOR REGION	0.00823	0.00276	0.00303	0.00588	-0.106***	-0.117***	-0.0743***	-0.0504*	0.653***	0.466***
	(0.00746)	(0.00557)	(0.00562)	(0.00555)	(0.0308)	(0.0301)	(0.0288)	(0.0285)	(0.145)	(0.144)
TRADE AGREEMENT			0.00502	-0.000831			0.697***	0.612***	0.294***	0.316**
			(0.00598)	(0.00589)			(0.120)	(0.117)	(0.111)	(0.129)
Observations	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216
R-squared					0.122	0.181	0.206	0.226		
ln(\lnalpha)										0.243**
										(0.121)

often located in less developed regions such as Africa and Asia where resource exploitation instead of pollution may be the major international environmental issue. As we will show later, countries with common official language are indeed more likely to have a resource related agreement.

For column two, the sum of logged GDPs has a positive effect which indicates that economically large countries are more likely to have a pollution agreement. If we increase the product of two countries' real GDPs by 10%, the probability of them having an environmental agreement increases by about 0.14%. The difference of logged GDPs has a positive but insignificant effect. Similar to column one, distance has a negative and significant effect, and the same region dummy has a significantly positive effect. The effect of common language becomes positive but insignificant.

We add the trade agreement dummy in column three and it has a positive but insignificant effect. The trade agreement variable includes various types of agreements including one-way preferential trade agreement, two-way preferential trade agreement, free trade agreement, and deeper trade agreements such as customs union. The effect we obtain may reflect an aggregate effect of various types of agreements. GDPs, distance, and the same region dummy have similar effect as those in column two. In column four, we add bilateral trade flow variable which has a significantly positive but relatively small effect. It indicates that countries with more bilateral trade are more likely to have a pollution agreement.

Panel 2 (the last six columns of Table 1) examines the number of pollution agreements two countries have. Columns 5 to 8 have the similar patterns with those in Panel 1. The last two columns show the results using Poisson and Negative Binomial regressions due to the count nature of the dependent variable. As mentioned above, results in this panel explore the intensity of countries' environmental coordination. The results are very consistent across various specifications. Economically larger countries and countries with similar size have more pollution agreements. Closer countries and those within the same region have more agreements. Countries with a trade agreement and those with larger trade flows tend to have more pollution agreements.

In column 5, distance has a significantly negative effect indicating that closer countries tend to have more pollution agreements. Countries within the same geographical region also tend to have more agreements. Countries with common language and located in neighboring regions have fewer agreements. In column 6, the sum of logged GDPs has a significantly positive effect, while the difference of logged GDPs has a significantly negative effect. This implies that economically larger countries and countries with similar economic sizes tend to have more pollution agreements. The trade agreement variable has a significantly positive effect on the number of agreements two countries have in column 7. In addition, countries with more bilateral trade flows have more pollution agreements as shown in column 8 which is the baseline result. In columns 9 and 10, we estimate Poisson and negative binomial regressions. As we can see, most variables in these two columns have similar effects with those in the baseline specification.

Table 3.2 Results for pollution agreements with greater than the 3rd quartile number of signatories

	1	2	3	4	5	6	7	8	9	10
	Panel 1 The likelihood of having an MEA				Panel 2 The number of MEAs two countries have					
VARIABLES	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	Poisson	Negative Binomial
SUM OF GDP		0.00927***	0.00895***	0.00117		0.439***	0.425***	0.196***	0.0352***	0.0322***
		(0.000933)	(0.000944)	(0.00108)		(0.0132)	(0.0132)	(0.0154)	(0.00264)	(0.00261)
DIFFERENCE IN GDP		0.00741***	0.00709***	0.00625***		0.108***	0.0959***	0.0926***	0.0166***	0.0233***
		(0.00166)	(0.00166)	(0.00154)		(0.0213)	(0.0213)	(0.0210)	(0.00343)	(0.00344)
SUM OF IMPORTS				0.00467***				0.108***	0.0149***	0.0155***
				(0.000343)				(0.00401)	(0.000583)	(0.000597)
DISTANCE	-0.0305***	-0.0235***	-0.0219***	-0.0118**	-0.543***	-0.269***	-0.199***	0.0814	0.00787	0.000941
	(0.00651)	(0.00626)	(0.00628)	(0.00601)	(0.0789)	(0.0746)	(0.0736)	(0.0718)	(0.0119)	(0.0128)
BORDER LENGTH	0.00445	0.00194	0.000957	0.00134	0.0806	-0.0343	-0.0700*	-0.0359	-0.00395	-0.00323
	(0.00421)	(0.00414)	(0.00418)	(0.00406)	(0.0500)	(0.0429)	(0.0412)	(0.0400)	(0.00590)	(0.00629)
COMMON LANGUAGE	-0.0255***	-0.0131*	-0.0152*	-0.0238***	-0.619***	-0.00420	-0.117	-0.347***	-0.0569***	-0.0588***
	(0.00768)	(0.00774)	(0.00782)	(0.00741)	(0.104)	(0.100)	(0.101)	(0.0972)	(0.0171)	(0.0180)
SAME REGION	-0.0371***	-0.0127	-0.0129	-0.00854	-0.779***	0.0720	0.0246	0.0294	-0.0156	-0.0551**
	(0.0124)	(0.0121)	(0.0121)	(0.0113)	(0.161)	(0.153)	(0.151)	(0.143)	(0.0255)	(0.0274)
NEIGHBOR REGION	0.0365***	0.0383***	0.0402***	0.0432***	0.944***	0.947***	1.054***	1.270***	0.194***	0.191***
	(0.0142)	(0.0138)	(0.0138)	(0.0131)	(0.159)	(0.151)	(0.151)	(0.147)	(0.0224)	(0.0238)
TRADE AGREEMENT			0.0506**	0.0157			1.737***	0.974***	0.125***	0.142***
			(0.0234)	(0.0236)			(0.236)	(0.226)	(0.0279)	(0.0307)
Observations	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216
R-squared					0.025	0.142	0.148	0.210		
ln(\lnalpha)										-1.437***
										(0.0344)

In Table 3.2, we present the results using pollution MEAs with more than 63 (3rd quartile) signatories. Some large agreements in this category, such as United Nations Framework Convention On Climate Change, may bias our results because they tend to be symbolic and have no binding commitments for the signatory countries. As a result, economic factors may not play a role here. The column 4 of Table 3.2 has the baseline result of the likelihood of having an agreement. The sum of logged GDPs has a positive but insignificant effect. The difference of logged GDPs has a significantly positive effect indicating that the larger the difference of two countries' economic sizes the more likely they will have a large pollution agreement. The same region dummy has a negative and insignificant effect. These three variables have insignificant or unexpected signs which confirm our previous prediction. Similar with the results by using small agreements, bilateral trade flows have a positive effect, and distance has a negative effect. The column 8 presents the results of the number of pollution agreements. Since the OLS estimation examines the relative numbers of agreements, the problems caused by those super large agreements are somehow relieved. As we can see, except for difference of logged GDP and distance, other explanatory variables have expected effects.

In this section, we estimate our specifications year by year from 1980 to 2000. We plot the marginal effects of each explanatory variable for probit model and OLS estimates for least square model. First, we present the results for agreements with fewer than 36 signatories in Figures 3.2 and 3.3. We present the results for those with more than 63 signatories in Figures 3.4 and 3.5. In Figure 3.2, we plot the marginal effect of probit and a 95% confidence interval of each explanatory variable year by year from 1980 to 2000. The sum of logged GDPs has a significantly positive and increasing effect over time which is consistent with what we have shown in Table 1. The difference in GDPs has a positive effect over time but the effect is insignificant in most of years. The bilateral trade flow variable has a positive and increasing effect over time. Distance has a negative effect and as time goes by the effect becomes larger. Border length and common language variables barely have significant effects over time. The same region variable has a significantly positive effect over time, while the effect of neighbor region is positive but insignificant in most of the years. The trade agreement variable has a positive effect in most of the years but this effect is not significant especially in most recent years.

In Figure 3.3, we plot similar graph for economic factors determining the number of small pollution agreements two countries have. The sum of GDPs has a positive and increasing effect over time, and the difference in GDPs has a negative effect over time. Both effects are statistically significant. Bilateral trade flows have a significantly positive effect over time. Distance and common language have negative effects, while same region has a positive effect over time. Trade agreement has a positive effect over time and the effect is significant in all years. All the important economic factors, economic size, distance, trade flows and trade agreement, have expected signs.

Figure 3.4 and 3.5 show the results for pollution agreements with more than 63 signatories. In Figure 3.4, several factors have mixed effects over time. For example, the difference in GDPs has a significant negative effect in early years but the effect becomes positive after mid-1990s. Also, distance has a negative effect before 1997 and a positive one from 1997 to 2000. As we argued above, the existence of some large agreements that include almost every country in the world may bias our results. OLS results shown in Figure 3.5 are similar with those have in Figure 3.3. The reason may be that OLS estimation compares the number of agreements and countries with more economic interactions tend to have more agreements which may not be affected by large agreements.

OLS results show the effects of explanatory variables on the conditional mean of the dependent variable. However, it is interesting to examine the effects on various quantiles of the conditional distribution of the dependent variable, especially is the dependent variable has a skewed distribution. We examine how economic factors may affect the number of agreements two countries have at different quantiles (0.25, 0.5, and 0.75). Table 3.3 shows the results of quantile regressions by using all pollution agreements for the year 2000. We show the baseline OLS results in the first column, which is followed by the results at 0.25, 0.5, and 0.75 quantiles in columns 2 to 4 respectively. Most of the independent variables in the last three columns have similar signs and magnitudes with those in the baseline OLS results.

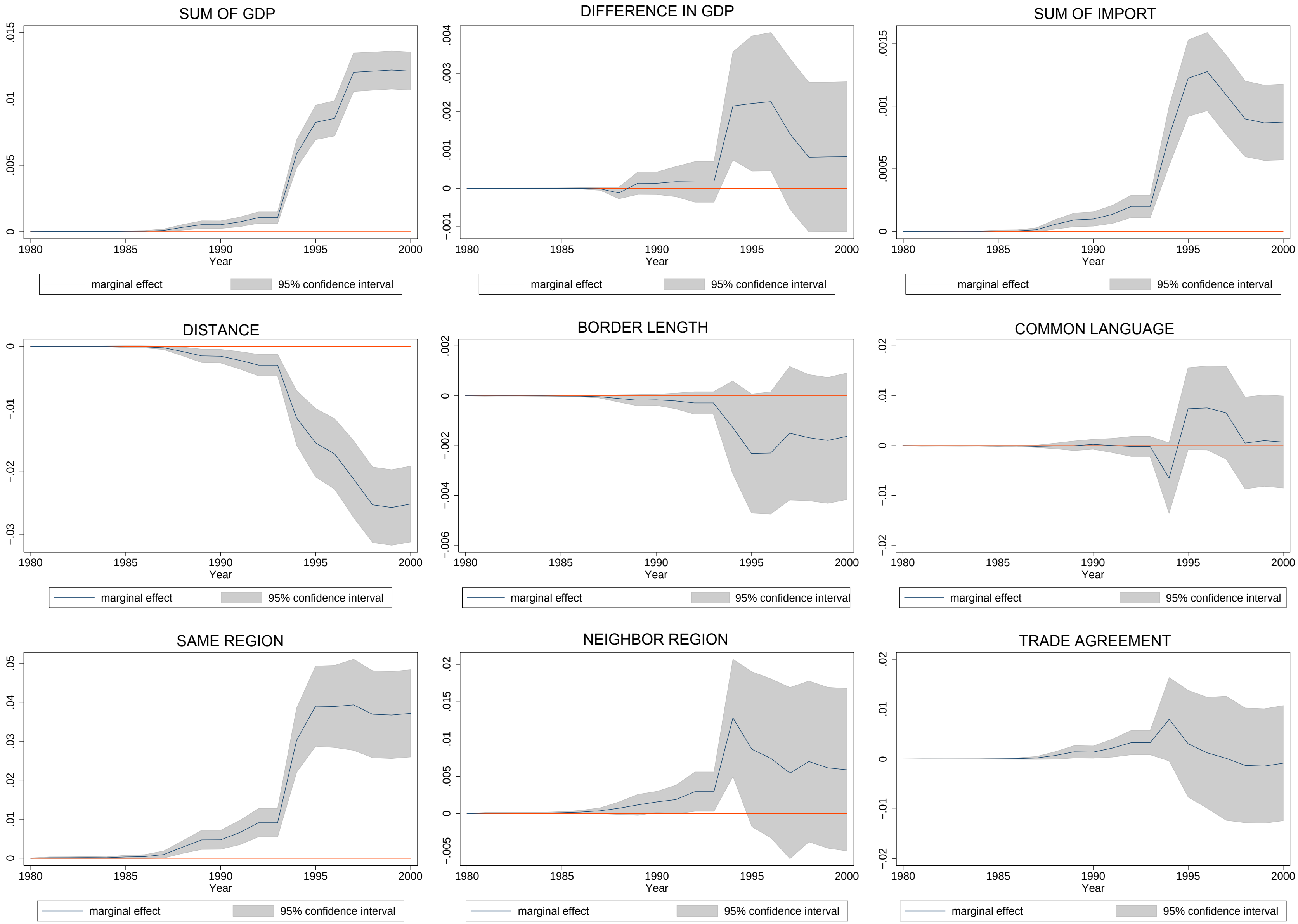


Figure 3.2 Probit results using pollution agreements with fewer than the median number of signatories

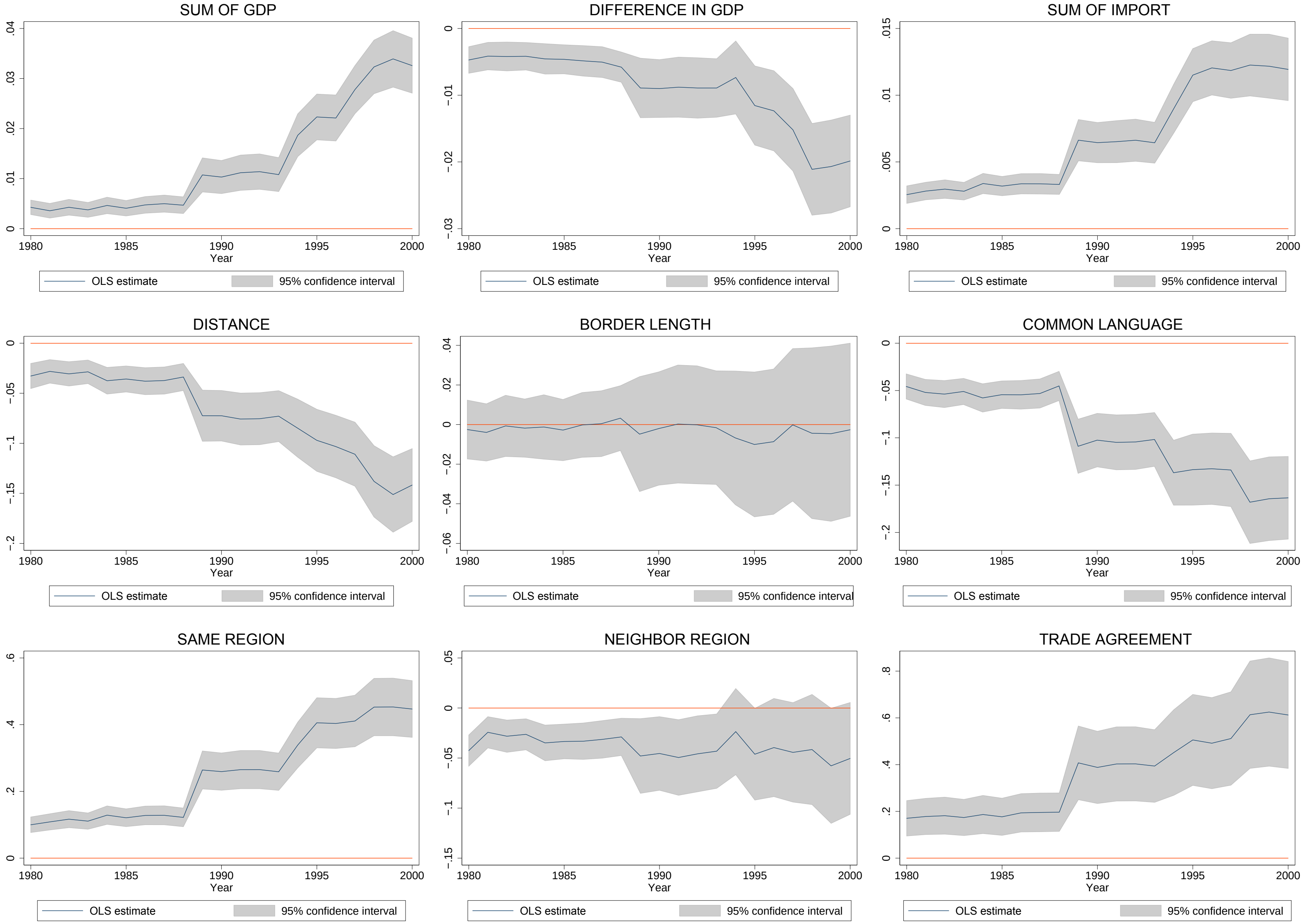


Figure 3.3 OLS results using pollution agreements with fewer than the median number of signatories

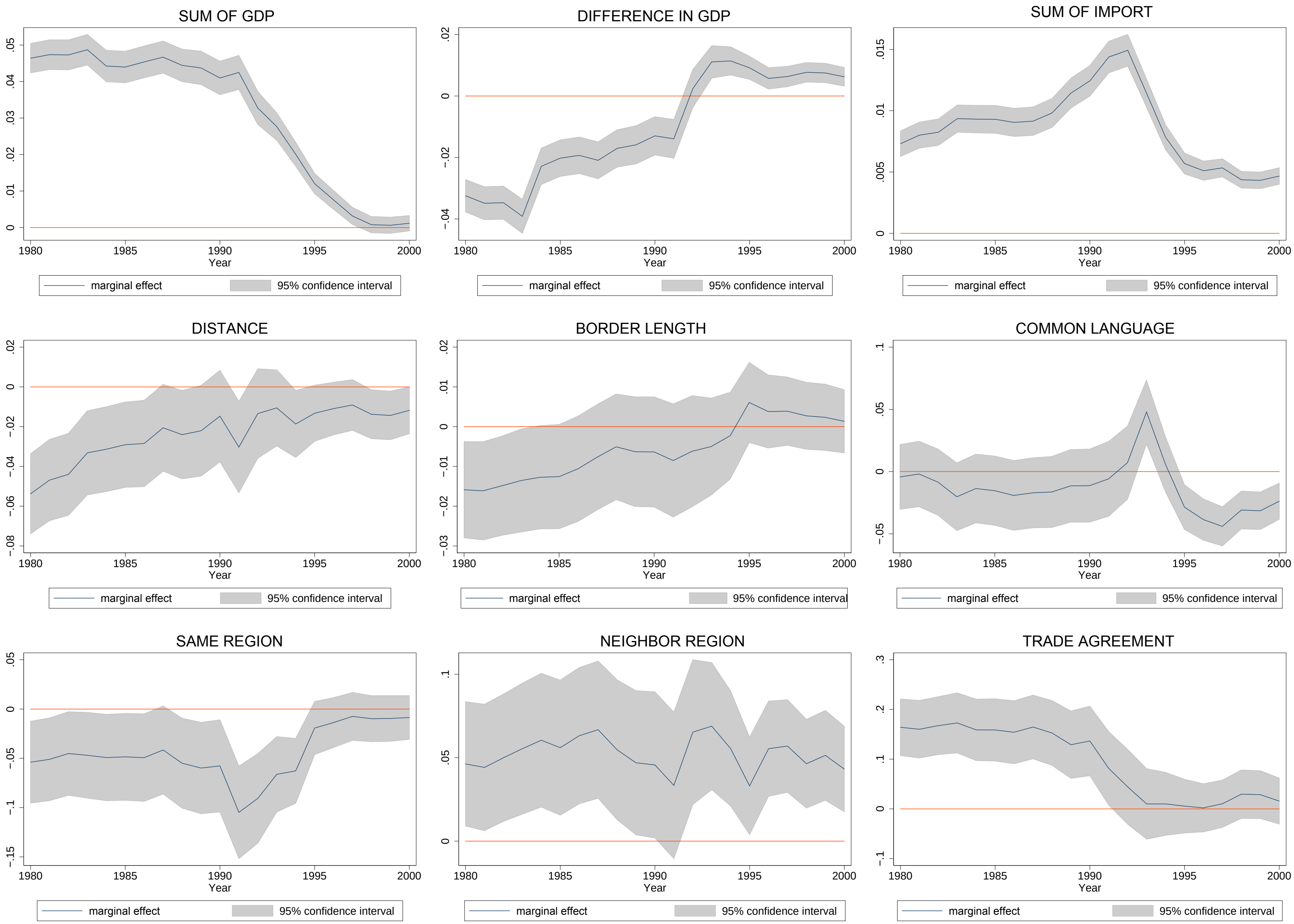


Figure 3.4 Probit results using pollution agreements with more than 3rd quartile number of signatories

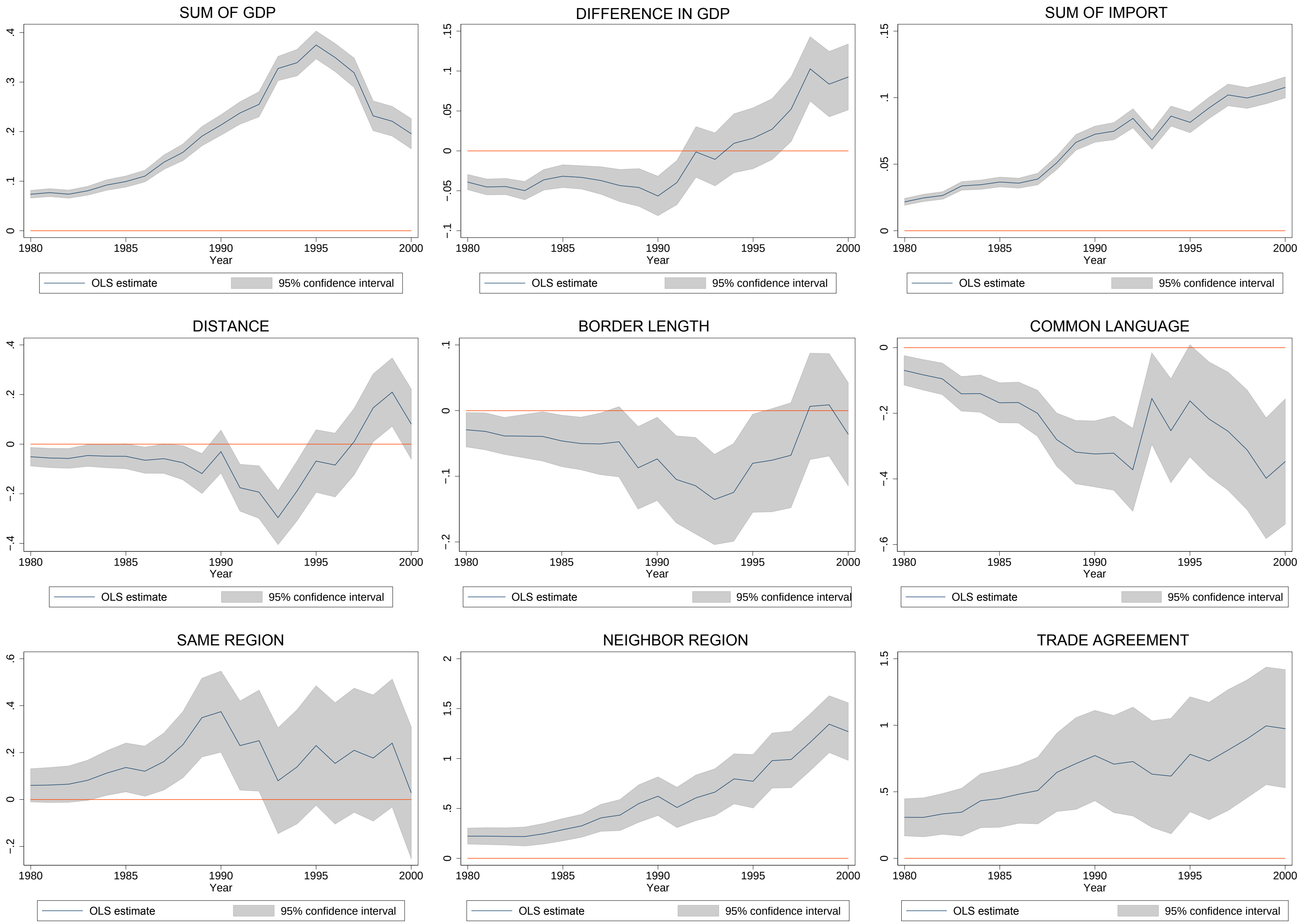


Figure 3.5 OLS results using pollution agreements with more than 3rd quartile number of signatories

Table 3.3 Results of quantile regressions for pollution agreements in 2000

	(1)	(2)	(3)	(4)
VARIABLES	baseline OLS	25th	50th	75th
SUM OF GDP	0.304***	0.185***	0.211***	0.398***
	(0.0180)	(0.0160)	(0.0143)	(0.0316)
DIFF IN GDP	0.0493**	-0.0406*	0.0257	0.326***
	(0.0238)	(0.0243)	(0.0249)	(0.0415)
SUM OF IMPORT	0.142***	0.0886***	0.173***	0.158***
	(0.00478)	(0.00418)	(0.00700)	(0.00791)
DISTANCE	-0.629***	-0.0115	-0.155*	-0.879***
	(0.0887)	(0.0858)	(0.0810)	(0.159)
BORDER LENGTH	-0.125**	0.0642	-0.0219	-0.190**
	(0.0523)	(0.0404)	(0.0752)	(0.0817)
LANGUAGE	-0.815***	-0.562***	-0.351***	-0.659***
	(0.117)	(0.147)	(0.0898)	(0.171)
SAME REGION	0.859***	0.0789	-0.0516	0.399
	(0.181)	(0.185)	(0.135)	(0.424)
NEIGHBOR REGION	1.620***	1.198***	1.819***	2.186***
	(0.172)	(0.166)	(0.267)	(0.261)
TRADE AGREEMENT	2.033***	0.973***	1.257***	2.127***
	(0.252)	(0.260)	(0.384)	(0.722)
Constant	5.058***	-0.134	1.853**	7.160***
	(0.867)	(0.843)	(0.802)	(1.547)
Observations	9,216	9,216	9,216	9,216
R-squared	0.298			

Table 3.4 shows the results of dynamic panel data analysis of pollution agreements with a small number of signatories. The first panel in Table 3.4 shows the results of Arellano–Bond estimation, while the second panel shows the results of Arellano-Bover/Blundell-Bond estimation. We implement both one-step GMM and two-step GMM in each method. In each specification, we use one lag of GDP variables and trade agreement variable.

Beginning with the Arellano–Bond estimators, we estimate one-step GMM with one lag of the number of agreements in column one. As expected, the lagged dependent variable has a positive effect indicating that the number of pollution agreements two countries have in the previous year has a positive effect on the number in the current year. For other explanatory variables, economically larger countries, countries with similar economic size, and those with trade agreements tend to have more pollution agreements. These results are consistent with those in the OLS and quantile regressions. In column two, we include two lags of the dependent variable. The twice lagged variable also has a positive effect although the magnitude is smaller than the once lagged variable. Other economic factors have similar effects with those in column one. The third and fourth columns show two-step GMM coefficients with one lag and two lags of the dependent variable respectively. As we can see, two-step GMM estimates are very similar in both signs and magnitudes with the one-step estimates. The last four columns show the results of Arellano-Bover/Blundell-Bond estimation. They are similar to those in the first four columns. The lags of dependent variable have positive effects. The sum of GDPs and similarity of GDPs have positive effects. And trade agreement also has a positive effect.

Table 3.4 Results of dynamic panel data analysis for pollution agreements

	1	2	3	4	5	6	7	8
		Arellano–Bond estimation				Arellano-Bover/Blundell-Bond estimation		
VARIABLES	one_step	one_step	two_step	two_step	one_step	one_step	two_step	two_step
L.MEA	0.968***	0.764***	0.968***	0.764***	0.960***	0.760***	0.960***	0.760***
	(0.00381)	(0.0222)	(0.00381)	(0.0222)	(0.00477)	(0.0259)	(0.0869)	(0.0533)
L2.MEA		0.213***		0.213***		0.216***		0.216***
		(0.0214)		(0.0214)		(0.0252)		(0.0195)
L.SUM_GDP	0.0405***	0.0368***	0.0405***	0.0368***	0.0600***	0.0630***	0.0598	0.0629*
	(0.00285)	(0.00251)	(0.00285)	(0.00251)	(0.00495)	(0.00501)	(0.0684)	(0.0380)
L.GDP_SIM	0.0230***	0.0196***	0.0230***	0.0196***	0.0250***	0.0243***	0.0252	0.0248
	(0.00168)	(0.00144)	(0.00169)	(0.00144)	(0.00258)	(0.00267)	(0.0595)	(0.0317)
L.TRADE AGREEMENT	0.00628***	0.00623***	0.00621***	0.00624***	0.00823***	0.00982***	0.00839	0.0101
	(0.00240)	(0.00211)	(0.00237)	(0.00211)	(0.00302)	(0.00279)	(0.0131)	(0.0368)
DISTANCE					-0.294*	-0.0643	-0.297	-0.0709
					(0.169)	(0.175)	(0.181)	(0.185)
BORDER LENGTH					-0.0361	-0.0697	-0.0382	-0.0692
					(0.0594)	(0.0653)	(0.0938)	(0.0566)
COMMON LANGUAGE					-1.119***	-0.813***	-1.115***	-0.807***
					(0.213)	(0.159)	(0.297)	(0.176)
SAME REGION					-0.724**	0.255	-0.721*	0.247
					(0.347)	(0.363)	(0.410)	(0.351)
NEIGHBOR REGION					-0.223	1.399***	-0.207	1.411***
					(0.374)	(0.335)	(0.508)	(0.387)
Constant					2.320	-0.0811	2.348	-0.0274
					(1.575)	(1.606)	(1.910)	(1.704)
Observations	542,039	536,208	542,039	536,208	543,410	537,687	543,410	537,687
Number of country pairs	18,100	18,100	18,100	18,100	17,898	17,898	17,898	17,898

3.4.2 Economic Determinants of Resource Related Agreements

We next investigate the economic factors that contribute to countries' cooperation on resource agreements. Table 3.5 shows the results using resource agreements with less than 10 (the median) signatories for year 2000. As before, panel 1 examines the likelihood of having an agreement, while panel 2 examines the number of agreements two countries have. Since most economic factors have consistent effects across various specifications, we mainly focus on column 4 which is the baseline result for probit model and column 5, the baseline result for OLS model. In column 4, for gravity variables, the sum of logged GDPs has a positive effect and the difference of logged GDPs has a negative effect which implies that economically larger countries and countries with similar economic sizes are more likely to have resource agreement with a relatively small number of signatories. The distance has a negative effect. Common language has a positive effect. As we argued before, many countries with the same official language are located in Africa or Asia which tend to rely more heavily on resource exploitation. For common resource variables, both border length and same region have significantly positive effects. For economic integration variables, both trade agreement and trade flows have positive effects. In column 5, these variables that influence the likelihood of having a resource agreement have similar effects on the number of agreements two countries have.

Table 3.6 presents the results using resource agreements with more than 28 (3^{rd} quartile) signatories. Trade agreement, trade flow, and distance have expected effects. Other factors like difference in GDPs and same region have contradicting effects. For example, countries within the same region are less likely to have an agreement but they tend to have more agreements.

Table 3.5 Results for resource agreements with fewer than the sample median number of signatories

	1	2	3	4	5	6	7	8	9	10
	Panel 1 The likelihood of having an MEA				Panel 2 The number of MEAs two countries have					
VARIABLES	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	Poisson	Negative Binomial
SUM OF GDP		0.00777***	0.00767***	0.00639***		0.0488***	0.0428***	0.0320***	0.261***	0.348***
		(0.000540)	(0.000532)	(0.000523)		(0.00419)	(0.00392)	(0.00385)	(0.0223)	(0.0216)
DIFFERENCE IN GDP		-0.00250***	-0.00272***	-0.00267***		-0.0197***	-0.0246***	-0.0248***	-0.113***	-0.151***
		(0.000627)	(0.000640)	(0.000626)		(0.00309)	(0.00340)	(0.00341)	(0.0312)	(0.0301)
SUM OF IMPORTS				0.000460***				0.00505***	0.00975**	0.0148***
				(9.59e-05)				(0.00109)	(0.00397)	(0.00426)
DISTANCE	-0.0263***	-0.0108***	-0.0104***	-0.00890***	-0.186***	-0.155***	-0.126***	-0.113***	-0.522***	-0.569***
	(0.00300)	(0.00193)	(0.00194)	(0.00191)	(0.0274)	(0.0258)	(0.0241)	(0.0233)	(0.0902)	(0.0820)
BORDER LENGTH	0.0136***	0.00591***	0.00594***	0.00603***	0.256***	0.243***	0.228***	0.230***	0.0662***	0.137***
	(0.00153)	(0.000896)	(0.000904)	(0.000895)	(0.0340)	(0.0330)	(0.0320)	(0.0319)	(0.0233)	(0.0236)
COMMON LANGUAGE	0.0218***	0.0266***	0.0256***	0.0242***	0.0611***	0.136***	0.0893***	0.0785***	0.874***	1.260***
	(0.00422)	(0.00270)	(0.00269)	(0.00259)	(0.0230)	(0.0228)	(0.0242)	(0.0246)	(0.124)	(0.121)
SAME REGION	0.0486***	0.0410***	0.0407***	0.0399***	0.200***	0.269***	0.250***	0.250***	1.481***	1.673***
	(0.00556)	(0.00453)	(0.00454)	(0.00445)	(0.0318)	(0.0328)	(0.0311)	(0.0310)	(0.171)	(0.158)
NEIGHBOR REGION	-0.00161	-0.000562	0.000353	0.00207	-0.191***	-0.203***	-0.158***	-0.148***	0.0323	-0.0545
	(0.00634)	(0.00386)	(0.00393)	(0.00387)	(0.0332)	(0.0331)	(0.0306)	(0.0299)	(0.199)	(0.182)
TRADE AGREEMENT			0.0138***	0.0106***			0.719***	0.683***	0.518***	0.589***
			(0.00396)	(0.00386)			(0.130)	(0.129)	(0.136)	(0.165)
Observations	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216
R-squared					0.209	0.244	0.270	0.274		
ln(\lnalpha)										0.638***
										(0.117)

Table 3.6 Results for resource agreements with greater than the 3rd quartile number of signatories

	1	2	3	4	5	6	7	8	9	10
	Panel 1 The likelihood of having an MEA				Panel 2 The number of MEAs two countries have					
VARIABLES	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	No GDPs, PTAs, or trade flows	No PTAs or trade flows	No trade flows	Baseline Results	Poisson	Negative Binomial
SUM OF GDP		0.00657***	0.00611***	0.000385		1.191***	1.149***	0.784***	0.0798***	0.0718***
		(0.000734)	(0.000732)	(0.000730)		(0.0285)	(0.0274)	(0.0256)	(0.00210)	(0.00205)
DIFFERENCE IN GDP		0.00221*	0.00189	0.00122		-0.347***	-0.382***	-0.387***	-0.0335***	-0.0267***
		(0.00126)	(0.00123)	(0.00101)		(0.0291)	(0.0296)	(0.0286)	(0.00263)	(0.00255)
SUM OF IMPORTS				0.00370***				0.171***	0.0118***	0.0122***
				(0.000262)				(0.00803)	(0.000533)	(0.000521)
DISTANCE	-0.0330***	-0.0273***	-0.0248***	-0.0141***	-2.514***	-1.765***	-1.560***	-1.115***	-0.103***	-0.0856***
	(0.00532)	(0.00511)	(0.00506)	(0.00426)	(0.166)	(0.131)	(0.129)	(0.125)	(0.00983)	(0.00967)
BORDER LENGTH	0.0168***	0.0137**	0.0125**	0.0119**	0.170	-0.153	-0.257**	-0.203*	-0.0212***	-0.0168***
	(0.00589)	(0.00581)	(0.00592)	(0.00494)	(0.147)	(0.119)	(0.116)	(0.112)	(0.00570)	(0.00538)
COMMON LANGUAGE	-0.00446	0.00484	0.00214	-0.00512	-2.187***	-0.383**	-0.714***	-1.080***	-0.0858***	-0.0636***
	(0.00621)	(0.00617)	(0.00607)	(0.00508)	(0.187)	(0.154)	(0.160)	(0.158)	(0.0140)	(0.0137)
SAME REGION	-0.0408***	-0.0251***	-0.0244***	-0.0161**	1.077***	2.880***	2.741***	2.749***	0.218***	0.176***
	(0.00919)	(0.00902)	(0.00885)	(0.00729)	(0.338)	(0.310)	(0.300)	(0.283)	(0.0217)	(0.0205)
NEIGHBOR REGION	0.00917	0.0106	0.0125	0.0147	1.152***	0.924***	1.236***	1.580***	0.142***	0.157***
	(0.0114)	(0.0109)	(0.0107)	(0.00908)	(0.278)	(0.236)	(0.234)	(0.228)	(0.0181)	(0.0178)
TRADE AGREEMENT			0.0946***	0.0581*			5.076***	3.863***	0.198***	0.187***
			(0.0345)	(0.0315)			(0.617)	(0.594)	(0.0265)	(0.0257)
Observations	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216	9,216
R-squared					0.111	0.361	0.377	0.426		
ln(\lnalpha)										-2.103***
										(0.0482)

We present the probit and OLS results for the resource agreements with less than 10 signatories in Figures 3.6 and 3.7 respectively. In Figure 3.6, gravity variables, the sum of logged GDPs has positive effects and the difference in logged GDPs has negative effects over time. Distance has a negative effect and common language has a negative effect over time. For economic integration variables, both bilateral trade flows and trade agreement have positive effects over time. For common resource variables, both border length and same region variables have positive effects over time. In Figure 7, our factors of most interest have similar effects across years.

In Figures 3.8 and 3.9, we present the probit and OLS results for resource agreements with more than 28 signatories. Several important economic factors, such as the sum of GDPs and same region dummy, do not have a consistent effect over time in Figure 3.8. However, the OLS results in Figure 3.9 are much better. Most economic factors have the expected signs.

Table 3.7 shows the quantile regression results of all resource agreements for the year 2000. Column one shows the baseline OLS results and columns 2 to 4 show the 0.25, 0.5, and 0.75 quantile regression results. Similar with the results by using pollution agreements, economic factors have consistent effects across OLS and various quantile regressions. Specifically, economic size, trade agreement, and bilateral trade flows have positive effects while distance has a negative effect on various quantiles of conditional distribution of dependent variable.

In Table 3.8, we show the results by using dynamic panel data analysis of resource agreements. Here we only focus on the resource agreements with less than 10 signatories (median). The dependent variable is the number of resource agreements two countries have in a year. Similar with the Table 3.4, the first panel in Table 3.8 shows the Arellano–Bond estimates while the second panel shows the Arellano-Bover/Blundell-Bond estimates. In each panel, we present one-step GMM estimate and two-step GMM estimates respectively. As we can see, explanatory variables of greatest interest show consistent effects across various estimation methods. Specifically, once lagged dependent variable has a significantly positive effect but twice lagged variable has insignificant effect. Economically larger countries and countries with similar economic sizes tend to have more resource agreements. One thing worth mentioning is that the effects of economic size variables are much smaller than those in Table 3.4. The trade agreement variable does not have a significant effect.

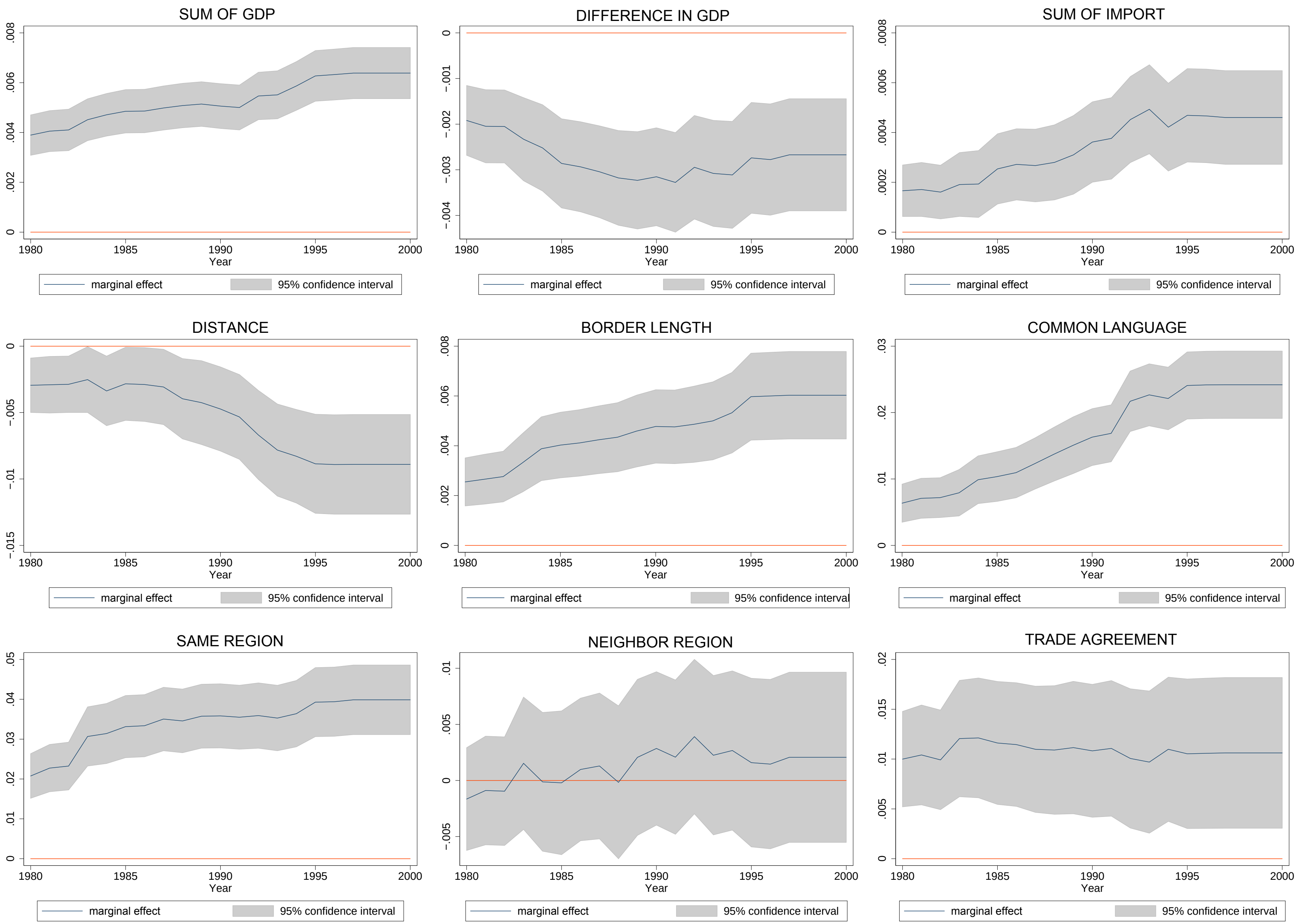


Figure 3.6 Probit results using resource agreements with fewer than the median number of signatories

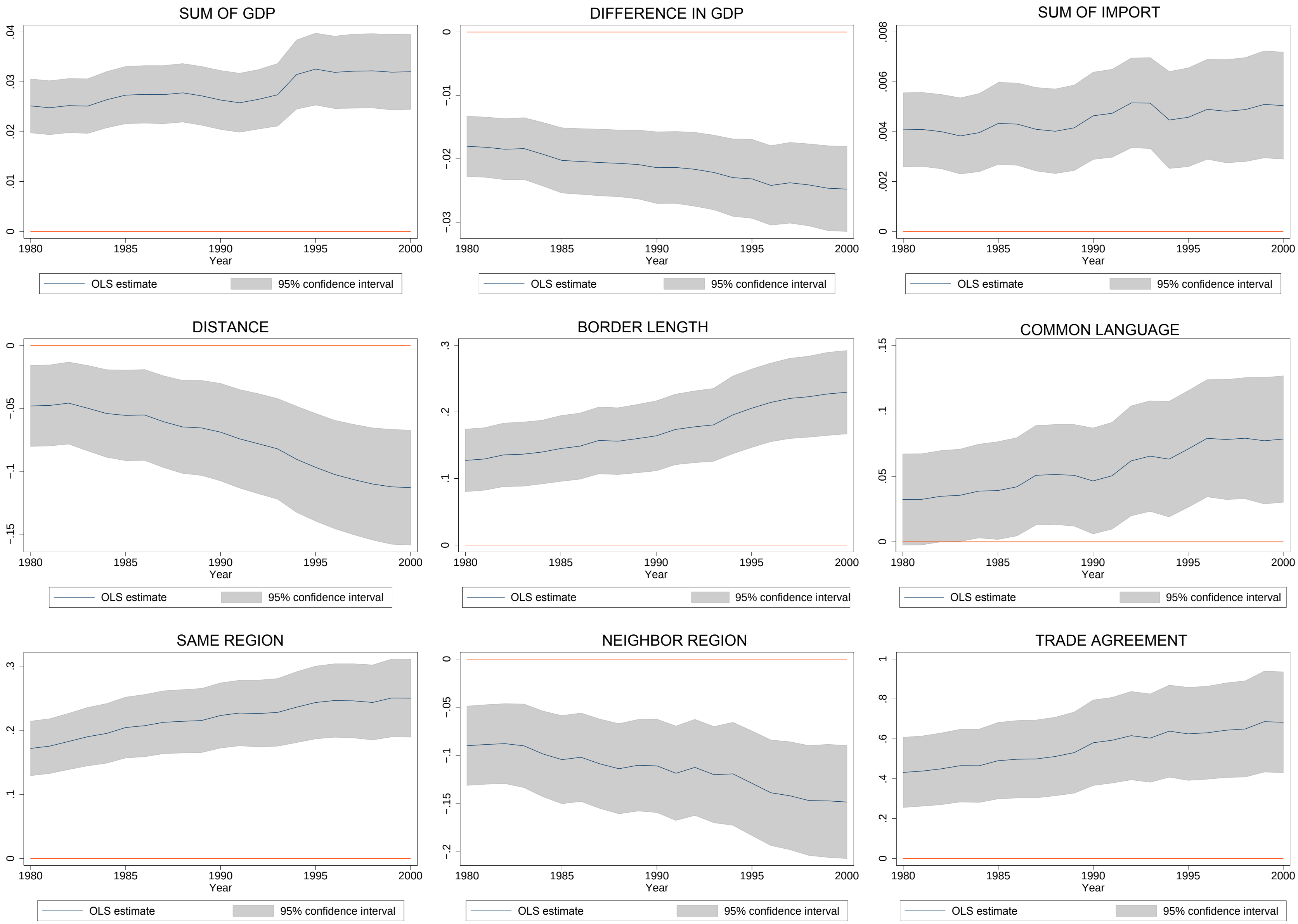


Figure 3.7 OLS results using resource agreements with fewer than the median number of signatories

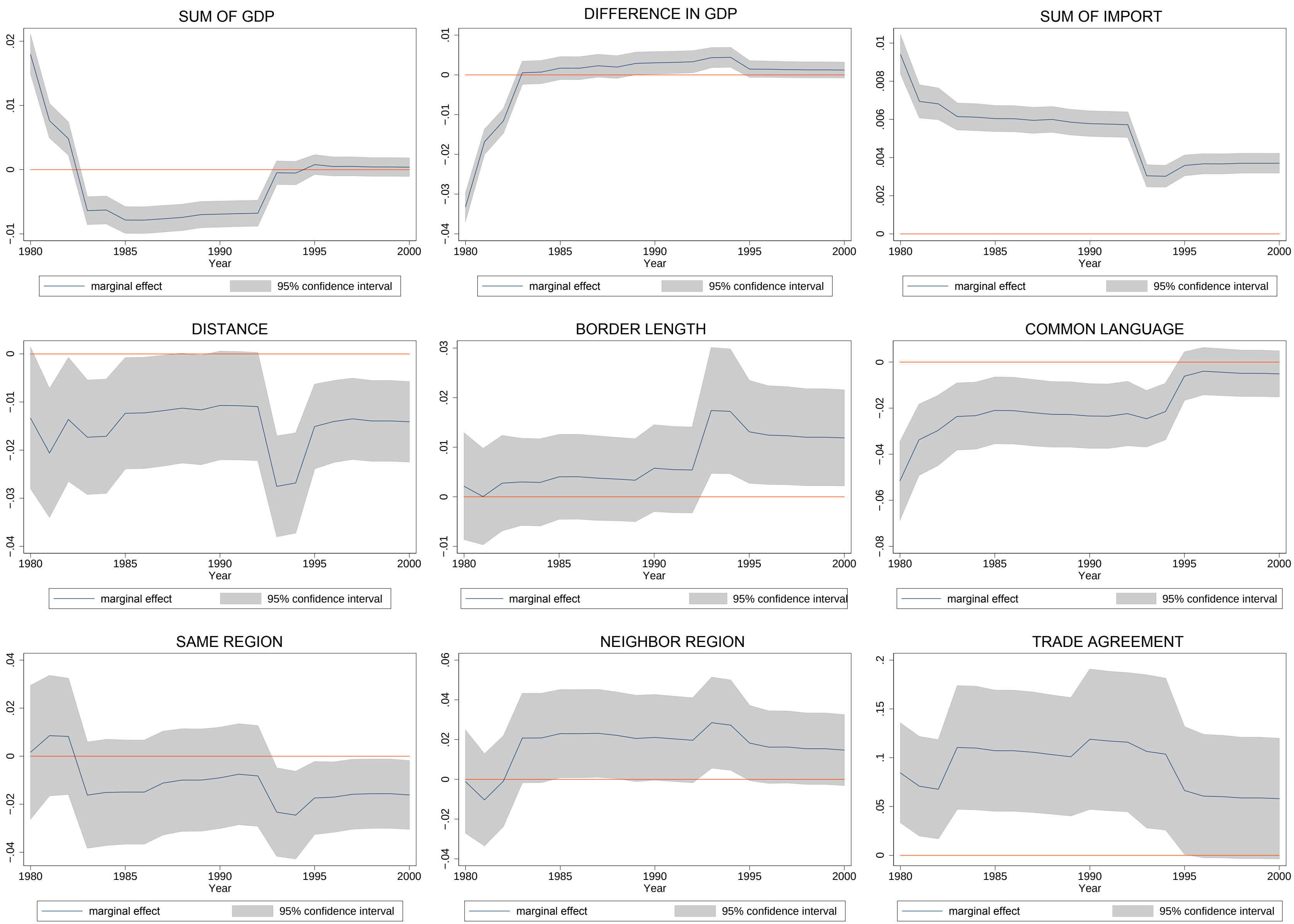


Figure 3.8 Probit results using resource agreements with more than 3rd quartile number of signatories

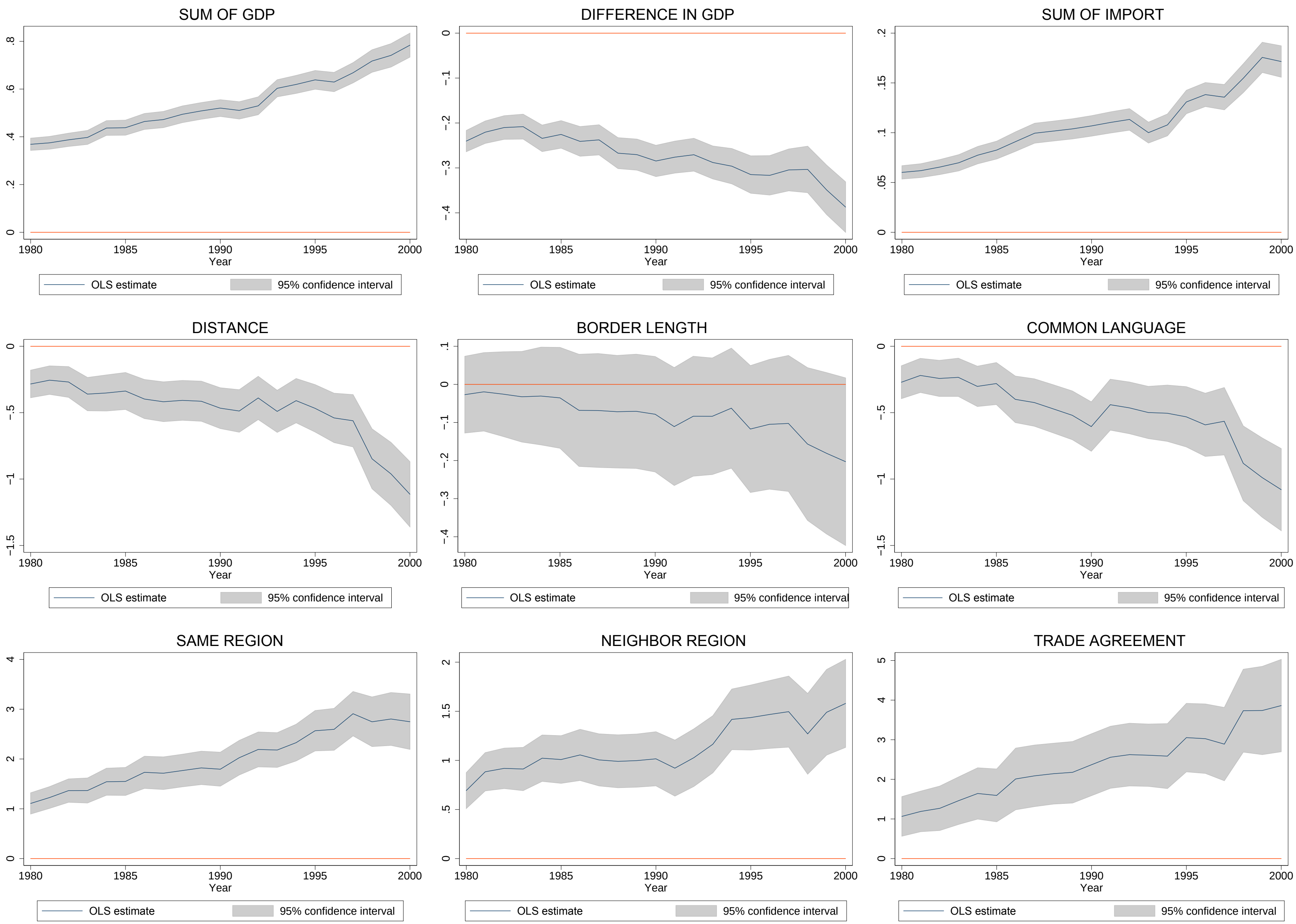


Figure 3.9 OLS results using resource agreements with more than 3rd quartile number of signatories

Table 3.7 Results of quantile regressions for resource agreements in 2000

	(1)	(2)	(3)	(4)
VARIABLES	baseline OLS	25th	50th	75th
SUM OF GDP	0.890***	0.538***	0.608***	0.746***
	(0.0259)	(0.0232)	(0.0196)	(0.0207)
DIFF IN GDP	-0.458***	-0.305***	-0.237***	-0.289***
	(0.0343)	(0.0306)	(0.0244)	(0.0240)
SUM OF IMPORT	0.190***	0.123***	0.134***	0.170***
	(0.00688)	(0.00612)	(0.00634)	(0.00930)
DISTANCE	-1.425***	-0.391***	-0.638***	-0.773***
	(0.128)	(0.120)	(0.106)	(0.113)
BORDER LENGTH	0.0813	0.231***	0.126*	0.175
	(0.0753)	(0.0742)	(0.0743)	(0.178)
LANGUAGE	-0.888***	-0.540***	-0.0247	0.204
	(0.168)	(0.171)	(0.127)	(0.142)
SAME REGION	3.849***	1.303***	1.779***	3.056***
	(0.261)	(0.236)	(0.260)	(0.262)
NEIGHBOR REGION	1.646***	1.573***	1.770***	2.256***
	(0.247)	(0.255)	(0.219)	(0.237)
TRADE AGREEMENT	5.307***	2.861***	1.841***	2.642
	(0.363)	(0.336)	(0.285)	(1.835)
Constant	5.709***	0.660	3.753***	4.682***
	(1.249)	(1.176)	(1.023)	(1.084)
Observations	9,216	9,216	9,216	9,216
R-squared	0.449			

Table 3.8 Results of dynamic panel data analysis for resource agreements

	1	2	3	4	5	6	7	8
		Arellano–Bond estimation				Arellano-Bover/Blundell-Bond estimation		
VARIABLES	one_step	one_step	two_step	two_step	one_step	one_step	two_step	two_step
L.MEA	0.965***	0.972***	0.965***	0.972***	0.976***	0.986***	0.976***	0.986***
	(0.00653)	(0.00882)	(0.00653)	(0.00882)	(0.00516)	(0.00766)	(0.151)	(0.184)
L2.MEA		-0.00167		-0.00167		-0.00622		-0.00621
		(0.00662)		(0.00663)		(0.00678)		(0.0521)
L.SUM_GDP	0.00387***	0.00486***	0.00377***	0.00485***	0.00317*	0.00384**	0.00300	0.00381
	(0.00117)	(0.00116)	(0.00116)	(0.00116)	(0.00187)	(0.00178)	(0.0509)	(0.0787)
L.GDP_SIM	0.00131*	0.00178**	0.00130*	0.00184**	0.000389	0.000621	0.000464	0.000781
	(0.000755)	(0.000749)	(0.000745)	(0.000743)	(0.00110)	(0.00107)	(0.0372)	(0.0809)
L.TRADE AGREEMENT	-0.000774	-0.000648	-0.000724	-0.000613	-0.00290	-0.00218	-0.00271	-0.00220
	(0.00169)	(0.00169)	(0.00160)	(0.00170)	(0.00183)	(0.00184)	(0.0600)	(0.122)
DISTANCE					-0.0675	-0.0594	-0.0649	-0.0583
					(0.0437)	(0.0432)	(0.248)	(0.258)
BORDER LENGTH					0.0184	0.0160	0.0188	0.0165
					(0.0168)	(0.0165)	(0.0436)	(0.144)
COMMON LANGUAGE					0.0881	0.0945*	0.0806	0.0921
					(0.0570)	(0.0557)	(0.145)	(0.259)
SAME REGION					-0.0264	-0.0334	-0.0235	-0.0334
					(0.126)	(0.128)	(0.154)	(0.404)
NEIGHBOR REGION					0.494***	0.477***	0.475	0.475
					(0.181)	(0.179)	(0.765)	(0.917)
Constant					0.494	0.417	0.478	0.410
					(0.404)	(0.400)	(1.822)	(2.041)
Observations	542,039	536,208	542,039	536,208	543,410	537,687	543,410	537,687
Number of tt	18,100	18,100	18,100	18,100	17,898	17,898	17,898	17,898

3.4.3 The Spillover effects between different types of agreements

In the last section, we examine whether countries' cooperation on pollution agreements may contribute to their cooperation on resource agreements or vice versus. The results are presented in Table 3.9. The first two columns show the result of the probit model, while the last two columns show the results of the OLS model. In column one, the dependent variable measures whether two countries have a pollution agreement in 2000. The variable, MEA_RESOURCE_DUMMY_1970, measures whether two countries have a resource agreement in 1970. If this variable has a positive effect, it would indicate that countries' cooperation on resource agreements may increase their likelihood to cooperate on pollution agreements. As we can see, it has a positive but insignificant effect. Other explanatory variables in column one have similar effects with what we have before. In column two, MEA_POLLUTION_DUMMY_1970 has a positive and significant (at 10%) effect indicating that countries' cooperation on pollution agreements may promote their cooperation on resource ones. In column three, MEA_RESOURCE_1970 measures the number of resource agreements two countries have in 1970 and it has a significantly positive effect. Similarly, in the last column, MEA_POLLUTION_1970 which measures the number of pollution agreements two countries have in 1970 also has a significantly positive effect. In addition, the spillover effect in column four is much larger than that in column three. This indicates that the effect of pollution agreements on resource agreements is much larger than the effect vice versus.

Table 3.9 Results of spillover effects among pollution and resource agreements

	1	2	3	4
	Probit		OLS	
VARIABLES	POLLUTION	RESOURCE	POLLUTION	RESOURCE
MEA_RESOURCE_DUMMY_1970	0.00672			
	(0.00682)			
MEA_POLLUTION_DUMMY_1970		0.0298*		
		(0.0159)		
MEA_RESOURCE_1970			0.551***	
			(0.0154)	
MEA_POLLUTION_1970				5.321***
				(0.102)
SUM_GDP_1970	0.0285***	0.0154***	0.0838***	0.0684***
	(0.00140)	(0.00106)	(0.00470)	(0.00414)
GDP_SIM_1970	0.0125***	0.0112***	0.0546***	0.0569***
	(0.00140)	(0.00108)	(0.00525)	(0.00466)
DISTANCE	-0.0283***	-0.0102***	-0.147***	-0.0851***
	(0.00314)	(0.00196)	(0.0136)	(0.0122)
BORDER LENGTH	-0.00235*	0.00613***	-0.0579***	0.220***
	(0.00135)	(0.000923)	(0.00824)	(0.00726)
COMMON LANGUAGE	0.00195	0.0263***	-0.167***	0.122***
	(0.00480)	(0.00273)	(0.0180)	(0.0161)
SAME REGION	0.0373***	0.0408***	0.385***	0.195***
	(0.00581)	(0.00455)	(0.0282)	(0.0252)
NEIGHBOR REGION	0.00342	0.000664	-0.0211	-0.107***
	(0.00563)	(0.00399)	(0.0266)	(0.0238)
TRADE AGREEMENT_1970	0.00433	0.0140***	0.540***	0.541***
	(0.00600)	(0.00405)	(0.0390)	(0.0348)
Constant			0.640***	0.216*
			(0.135)	(0.120)
Observations	9,216	9,216	9,216	9,216
R-squared			0.303	0.438

3.5 Conclusion

In this paper, we separately examine the economic determinants of pollution related agreements and resource related agreements. Pollution agreements mainly deal with pollution affecting air, land, oceans, or freshwater system. Resource related agreements include those dealing with natural resource, habitat, freshwater resource, ocean, and species. The former category addresses various forms of pollution, while the latter one mainly focuses on the conservation of natural resources. Using Ronald Mitchell's International Environmental Agreement database (2002-2016), we find that economic size, distance, trade agreements, and bilateral trade flows have statistically significant effects on countries' coordination on both pollution related agreements and resource related agreements. These results are most robust for the MEAs between a small numbers of countries. In addition, we find the evidence that countries' cooperation on pollution agreements may contribute to their cooperation on resource agreements and vice versus.

CHAPTER 4

ECONOMIC DETERMINANTS OF TIMING OF MULTILATERAL ENVIRONMENTAL AGREEMENTS

4.1 Introduction

In recent years, news related to international pollution such as global warming, acid rains, oil spills, and the transboundary movement of hazardous wastes is always able to attract public attention. Many of these problems are rather urgent and require countries' immediate action to protect the environment before it is too late. Since no country can solve this kind of environmental issue alone, countries need to coordinate with each other through international environmental agreements. We observe that some countries cooperate on environmental agreements early, while others cooperate late. In this paper, we examine the economic determinants of the timing of countries' cooperation on international pollution agreements.

We examine the most comprehensive list of pollution agreements by using Ronald Mitchell's International Environmental Agreement Database Project (2002-2016). The first pollution agreement in the data is the International Convention for The Prevention of Pollution of The Sea by Oil which entered into force in 1958 and has been ratified by 71 countries.[2] Since then, another 41 agreements were formed to examine

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[2] Following recent empirical research on MEAs (Egger et al., 2011, 2013; Millimet and Roy, 2014), we only focus on those recent pollution agreements which were formed after the World War II. In addition,

various pollution issues which can be categorized into three groups: air pollution, marine pollution, and waste pollution (Ronald Mitchell, 2016). The number of signatories of these agreements varies from 3 to 196. Figure 1 shows the annual count of the number of pollution agreements over time.

There are a large number of game-theoretic papers exploring the formation and characteristics of international environmental agreements (e.g. Barrett, 1994, 1997, 2001; Carraro and Siniscalo, 1993, 1998; Hoel, 1992; Hoel and Schneider, 1997; Rubio and Ulph, 2003; Finus et al 2005). Their basic findings suggest that the number of countries in an agreement is likely to be very small and that self-enforcing international environmental agreements with a large number of signatories may not be able to improve substantially beyond what countries can do without any agreements. On the other hand, there are a small but growing number of empirical papers on multilateral environmental agreements. Egger et al. (2011, 2013) argue that countries with more liberalized trade and investment policies tend to ratify more multilateral environmental agreements. Besedes et al. (2016) examine the economic determinants of countries' cooperation on multilateral environmental agreements. They find that economic size, distance, and economic integration variables contribute to countries' coordination.

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there are three types of agreements in the IEA database: main agreements, protocols, and amendments. We only use main agreements in our analysis and drop out protocols and amendments.

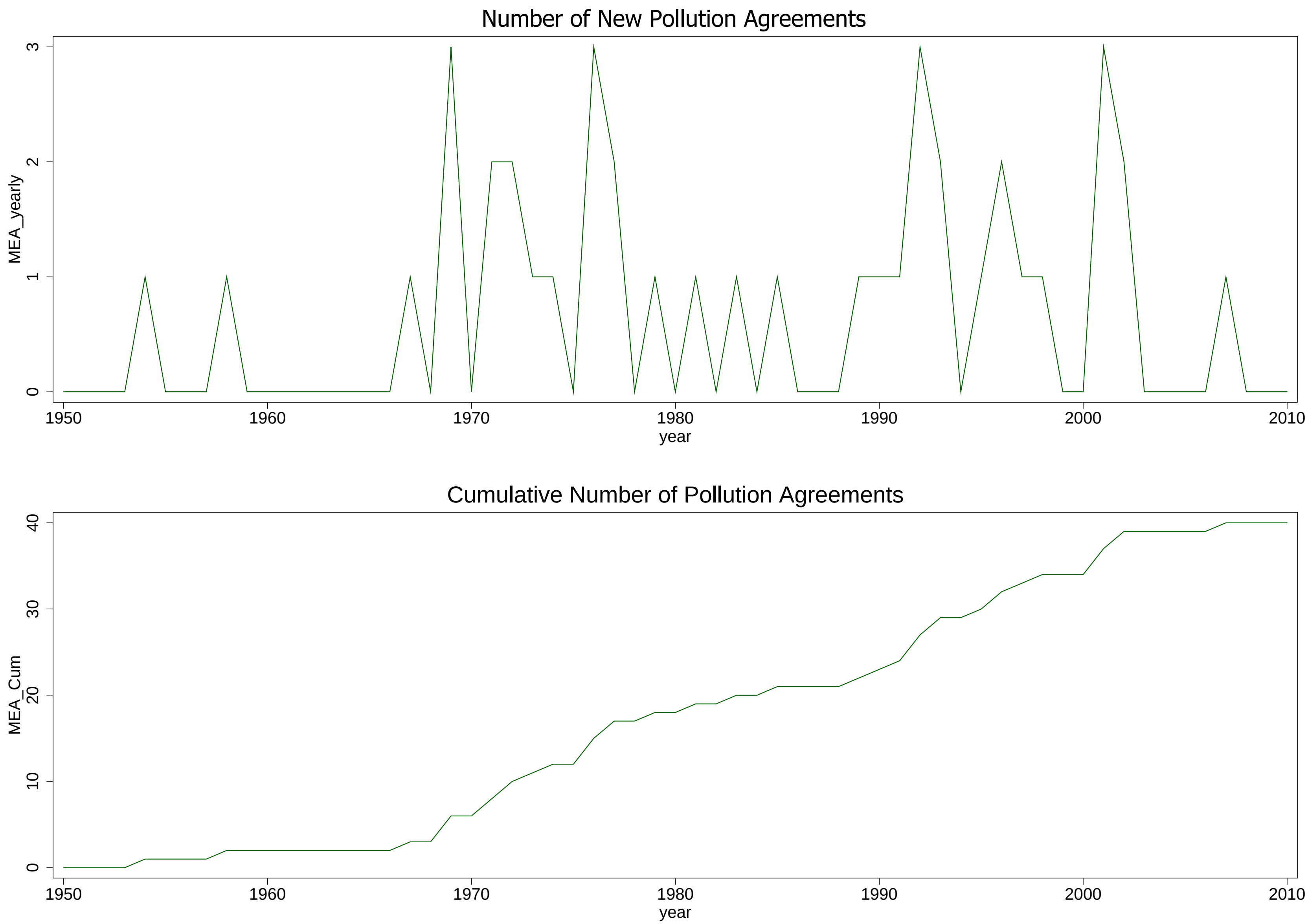

Figure 4.1 Annual count of pollution agreements over time

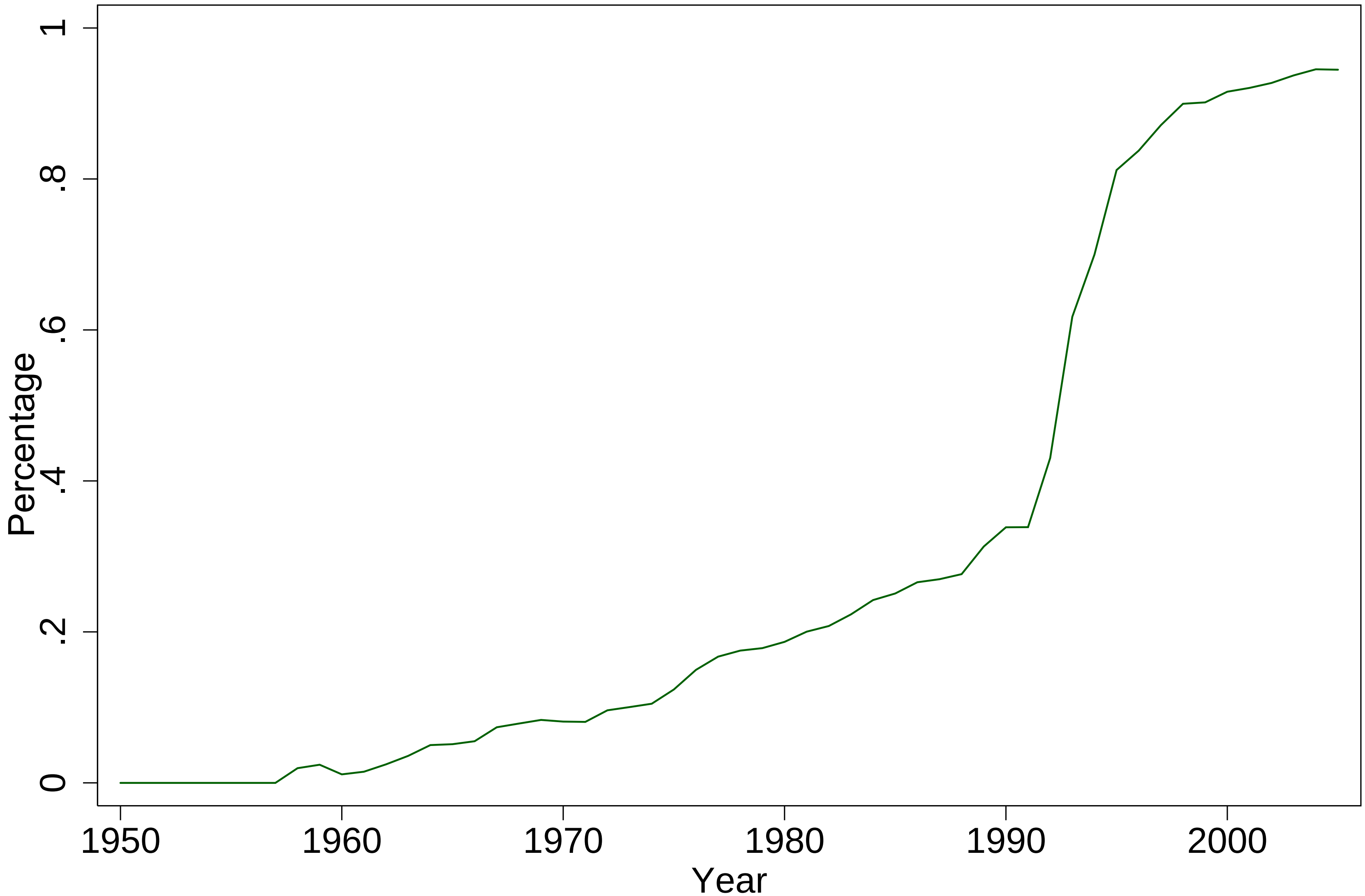

Figure 4.2 Percentage of countries having a pollution agreement

Apart from previous research, we employ duration analysis to examine countries' cooperation on pollution treaties. Our goal is to examine the economic factors that influence how long it takes two countries to sign their first agreement as well as any subsequent ones. Specifically, we first examine how long it takes two countries to have an MEA since 1950. After having an MEA or a set of them, most countries continue to cooperate on other environmental treaties in the following years. To understand this process, we then examine how long it takes two countries to have another agreement conditional upon having already had a number of them. Why is the examination of having an additional agreement important? Unlike trade agreements which are always comprehensive such as The Trans-Pacific Partnership (TPP), an environmental agreement often focuses on a specific environmental issue. For example, the Kyoto Protocol is used to control the emission of CO2, while the Basel Convention deals with the international movement of hazardous wastes. As a result, two countries often have only one trade agreement but have a number of environmental agreements. In addition, as we know, the implementation of environmental agreements, especially those pollution related, incur economic costs. After ratifying an agreement, countries may wait and see whether and how costly it is. If the cost is much larger than the benefit, countries may wait a longer time to ratify another one or never try again. As a result, it is interesting to examine countries' decisions to have an additional agreement.

In our context, the hazard rate refers to the likelihood of two countries having an agreement in a certain year conditional upon not having had one until that year or the probability of having another agreement conditional upon already having some. Economic factors of interest to us include economic size, distance, and economic integration levels the role of which is examined in Besedes et al. (2016) to examine the likelihood of countries having an agreement as well as the number of agreements they have.

Our econometric method is motivated by Hess and Persson (2012) in which the authors use discrete-time models to replicate the influential study of the duration of trade by Besedes and Prusa (2006). They show that discrete-time models, especially the random-effects probit model, are more suitable than the traditional Cox proportional hazards models in analyzing duration of trade flow, as the Cox model was developed with continuous-time data in mind. Because of the similar structure of our data and trade duration data, we also employ random-effects probit model to examine the timing of MEAs. This model has three advantages compared to Cox models: 1) it can deal with tied duration times; 2) it can more easily account for unobserved heterogeneity; and 3) it is not restricted by the proportional hazards assumption. The complementary log-log model, which is used to examine the timing of free trade agreement (Bergstrand et al., 2016), also assumes that the hazards of two subjects are proportional to each other and is thus less desirable of an approach.

Our results show that economic size, distance, existence of a trade agreement, and trade flows shift the hazard of two countries having their first agreement or another one. Countries without any agreement become more likely to sign one as time passes. In other words, conditional on not having an agreement, the hazard of signing the first agreement is increasing with duration. However, this effect changes if the two countries have an agreement. In that case, the hazard of signing an additional agreement is decreasing with duration. This effect is at least partially offset the greater the number of pollution agreements two countries have. By comparing the estimated hazards, we further show that the likelihood of having an addition agreement conditional on already having had some is much larger than the likelihood of having the first agreement. This result indicates that countries' previous experience on environmental cooperation may contribute to their future cooperation.

4.2 Econometric Model

We employ a discrete-time duration analysis to examine the timing of countries' cooperation on pollution related agreements. Depending on the characteristics of the data generating process or the available data, duration analysis employs either continuous-time analysis or discrete-time analysis. We focus on discrete-time analysis using the random effects probit estimator for several reasons. First, we can only observe the number of years until two countries have another agreement which means that our data have been grouped into discrete intervals of time (years). Second, many observations in our data have the same duration when a failure occurs ("ties"), which in our application is when the two countries sign an agreement. Third, discrete-time analysis can easily address unobserved heterogeneity. Fourth, the venerable Cox semiparametric hazard model assumes that the hazard of any two subjects is proportional to each other at any point during the duration of the spells of the two subjects. This assumption does not allow for the ratio of the two hazards to change with duration. This restriction is alleviated by our use of the random effects probit estimator.

Following Jenkins (2005), it is easy to show that the maximum likelihood function for a discrete time duration model and a binary choice model are exactly the same. We assume that the hazard rate for countries A and B to have a pollution agreement in year $t$is:

$$h_{ABt} = \Pr(T_{AB} = t | T_{AB} \geq t). \qquad (1)$$

In our context, this hazard refers to: 1) the probability of two countries having a pollution agreement conditional on not having had one until year t; and 2) the probability of two countries having another pollution agreement conditional on already having had some agreements in year t. We observe a country pair AB's spell from the first year to the last one, t_{AB}, which is country pair specific. In the last year, t_{AB}, the two countries' spell is either complete ($c_{AB} = 1$), or right censored ($c_{AB} = 0$). Then, the likelihood contribution for a complete spell is

$$\mathcal{L}_{AB} = \Pr(T_{AB} = t_{AB}) = \frac{h_{ABt}}{1 - h_{ABt}} \prod_{t=1}^{t=t_{AB}} (1 - h_{ABt}), \qquad (2)$$

while the likelihood contribution for a right censored spell is

$$\mathcal{L}_{AB} = \Pr(T_{AB} > t_{AB}) = \prod_{t=1}^{t=t_{AB}} (1 - h_{ABt}). \qquad (3)$$

The likelihood for the whole sample is

$$\begin{aligned} \mathcal{L} &= \prod_{AB=1}^{n} [\Pr(T_{AB} = t_{AB})]^{c_{AB}} [\Pr(T_{AB} > t_{AB})]^{1-c_{AB}} \\ &= \prod_{AB=1}^{n} [(\frac{h_{ABt}}{1 - h_{ABt}})^{c_{AB}} \prod_{t=1}^{t=t_{AB}} (1 - h_{ABt})]. \qquad (4) \end{aligned}$$

This implies that

$$log\mathcal{L} = \sum_{AB=1}^{n} c_{AB} \log\left(\frac{h_{ABt}}{1 - h_{ABt}}\right) + \sum_{AB=1}^{n} \sum_{t=1}^{t_{AB}} \log(1 - h_{ABt}) . \quad (5)$$

Now we define y_{ABt} as the MEA dummy variable. For the spells in which two countries have no agreements, y_{ABt} equals to one if two countries have a pollution agreement and zero otherwise, while for the spells in which two countries already have some agreements, y_{ABt} is equal to one if two countries have another agreement and zero otherwise. When the spell is complete ($c_{AB} = 1$), $y_{ABt} = 1$ if $t = t_{AB}$, and $y_{ABt} = 0$ otherwise. When the spell is right censored ($c_{AB} = 0$), y_{ABt} is always equal to zero. Hence, equation (5) can be written as

$$log\mathcal{L} = \sum_{AB=1}^{n} \sum_{t=1}^{t_{AB}} [y_{ABt} \log h_{ABt} + (1 - y_{ABt}) \log(1 - h_{ABt})] \quad (6)$$

which has the exactly same form as the traditional log likelihood function for binary response models.

In order to estimate the model parameters, we have to specify a functional form for the hazard rate h_{ABt}. Following Hess and Persson (2012), we estimate a discrete hazard using random effect probit with the following specification

$$h_{ABt} = \Phi(\boldsymbol{X}_{ABt}\boldsymbol{\beta} + \theta_t + \varepsilon_{AB}) \quad (7)$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function, $\boldsymbol{X}_{ABt}$ is the set of explanatory variables and θ_t captures the general time trend. We assume $\theta_t = \gamma \ln(t)$ where t measures the number of years since the beginning of the spell, while ε_{AB} measures the random effect.

4.3 Data

Multilateral environmental agreement data come from Ronald Mitchell's International Environmental Agreement Database Project (2002-2016). Basic information on multilateral environmental agreements includes subject or topic of the agreement, its beginning date, and membership. Treaties are categorized into eight subjects: energy, freshwater resources, habitat, nature, oceans, weapons and environment, pollution, and species. In addition, agreements dealing with pollution are further divided into four categories: pollution related to air, land, ocean, and waste. Member countries and the date when those members ratified the agreement are identified in the database.

Explanatory variables in our specifications mainly come from Besedes et al. (2016). There are two sets of explanatory variables: gravity variables and economic integration variables. In addition, to explore how the number of MEAs two countries already have may affect their probability of having another one, we include the number of agreements two countries have during the spell.

To be more specific, gravity variables include sum of logarithm of GDPs, difference of logarithm of GDPs, logarithm of distance between two countries' economic center, common border dummy, and common official language dummy. These gravity variables come from the CEPII gravity database. Economic integration variables include a trade agreement dummy variable and the value of bilateral trade flows. Since there are various types of trade agreements, we attempt to examine how they may affect countries' cooperation on pollution issues differently. Following Baier, Bergstrand, and Feng (2014), we group EIAs into three types: one-way PTAs, two-way PTAs and FTAs and deeper integration agreements (including custom unions, common markets, and economic unions). Data on trade agreements are from the Database on Economic Integration Agreements compiled by Scott Baier and Jeffrey Bergstrand (2007). Bilateral trade flow data are aggregated from 4-digit SITC UN Comtrade data.

4.4 Results

We first examine the economic factors that shift the hazards of having the first agreement or another one. After obtaining the coefficients, we plot the estimated hazards over time. Our results show that economic size, distance, and economic integration variables influence the hazards of countries' cooperation on pollution agreements. In addition, the hazard of having an additional agreement is always larger than the hazard of having the first one.

4.4.1 Economic Determinants of Various Hazard Rates

In this section, we discuss the main empirical results for various hazard rate specifications. The first hazard rate specification refers to the probability of having a pollution agreement in a certain year conditional on not having had one until that year. Since most country pairs in our sample have more than one pollution agreement, we examine the probability of having another agreement conditional on already having had one. This is the second hazard rate specification. The additional hazard rate specification are for instances when countries progressively add more agreements. We explore the hazard of signing additional agreements up to the sixth agreement two countries could have. In 2005, the last year in our sample, the mean of the number of agreements two countries have is 4.14, the median is 4, and the third quartile is 5. The minimum and maximum number is 0 and 20 respectively. After analyzing different hazards separately, we pool all the data in our sample and examine the average hazard which can be referred as the probability of having another agreement conditional on having already had some (include zero).

To estimate each of the hazards above, we first only include geographic variables such as distance, border, and common language. We then add GDP variables which are followed by adding trade agreement variables and trade flow variables. I also include the log of time variable in each specification which measures the number of years since the beginning of the spell.

Our main results show that economic size, distance, and trade integration variables shift the hazard of two countries having their first agreement or another one. In addition, the time variable has a positive effect on the hazard conditional on two countries having no agreements before, but the effect changes to be negative if two countries already have some agreements and for the pooled regression. Furthermore, the more agreements two countries currently have, the sooner they will have another one. In other words, the number of agreements has a positive effect on the hazard rate of having more agreements.

Table 4.1 presents the results using geographic variables only. As we can see, columns 1 to 7 show the results for hazard rates conditional on different number of agreements two countries already have, while column 8 shows the results of the pooled regression. In column one, we examine the probability of two countries signing a pollution agreement in a certain year conditional on not having had one until that year. As we can see, distance has a negative and significant effect on the hazard rate of signing the first agreement which implies that closer countries tend to have their first agreement earlier. As argued in Besedes et al. (2016), countries that are closer to each other may have more economic and cultural interactions which may facilitate their coordination on solving international pollution issues. Our results confirm this argument in a dynamic circumstance. Border has a significantly positive effect which means that countries sharing a border tend to have their first agreement in a shorter period of time. Common language has a negative and significant effect on the hazard rate. Most country pairs sharing official language are less developed ones. For example, there are 67 countries where English is an official language. However, most of these countries are located in less developed areas such as Africa, the Caribbean, or Asia. These countries are relatively less industrialized so international pollution issues may not be severe for them especially in the early years. The time variable has a positive and significant effect on the hazard rate which indicates that the longer two countries have no agreement, the higher the probability in any period that it will have one.

In the second column, we examine the probability of two countries having another agreement conditional on already having had one. Distance has a significant positive effect. In other tables we can also observe the positive effect of distance for countries that already have one MEA. The reason may be as follows. As shown in the first column, countries closer to each other often have their first agreement in a short period of time after 1950. Many country pairs had their first agreement in the 1960s or the 1970s. However, most of pollution agreements entered into force in the 1990s. It is very possible that some countries closer to each other had their first agreement in the 1960s and a second set in the 1980s, while some distant countries had both their first and second agreements in the 1990s. This may explain why we observe unusual effects for distance. This reasoning may also apply for common language which has a positive effect.

Table 4.1 Gravity variables without GDPs

VARIABLES	1 Conditional on MEA=0	2 Conditional on MEA=1	3 Conditional on MEA=2	4 Conditional on MEA=3	5 Conditional on MEA=4	6 Conditional on MEA=5	7 Conditional on MEA=6	8 Polled regression
DISTANCE	-0.109***	0.0863***	-0.114***	-0.148***	-0.150***	-0.128***	-0.156***	-0.0496***
	(0.00539)	(0.00777)	(0.00834)	(0.00999)	(0.0112)	(0.0285)	(0.0170)	(0.00267)
BORDER	0.127***	0.136***	-0.128***	-0.105*	-0.0604	-0.0947	-0.133	0.0326*
	(0.0349)	(0.0478)	(0.0490)	(0.0570)	(0.0655)	(0.0815)	(0.0991)	(0.0168)
COMMON LANGUAGE	-0.129***	0.0462***	-0.0783***	-0.0784***	0.00717	0.0285	-0.0680*	-0.0480***
	(0.0103)	(0.0148)	(0.0164)	(0.0196)	(0.0243)	(0.0306)	(0.0382)	(0.00537)
ln_t	1.361***	-0.0786***	-0.0475***	-0.114***	-0.0997***	-0.0736	-0.110***	-0.118***
	(0.0222)	(0.00620)	(0.00754)	(0.00920)	(0.0112)	(0.0993)	(0.0189)	(0.00188)
MEA								0.132***
								(0.00108)
Constant	-5.832***	-1.554***	0.153**	0.296***	0.306***	0.0362	0.292**	-1.139***
	(0.0807)	(0.0698)	(0.0741)	(0.0884)	(0.0988)	(0.173)	(0.148)	(0.0243)
Observations	1,104,806	70,772	61,379	51,828	34,363	23,665	14,137	1,378,944
Number of country pairs	24,624	13,830	13,237	11,624	7,453	5,121	3,185	83,166

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The time variable has a negative effect. As we can see, the time variable has a negative effect on the hazard if two countries already have some agreements. The possible reason is as follows. There are some large agreements (three of them with more than 150 signatories) including almost all the countries in the world entered into force in the early 1990s. As mentioned before, the mean of MEA is four. So it is possible that after agreeing to such large agreements many countries just do not cooperate on MEAs anymore. This may be one reason that can explain the negative effect of time.

We present the results for countries already having had two agreements in column three. As we can see, most variables have the expected signs again. Both distance and common language have negative and significant effects. The time variable also has a negative effect. Different from results in the first two columns, the effect of border also changes to be negative. In column four, we examine how long it takes two countries to have another agreement conditional on them already having three agreements. Similar with what we have in column three, distance, common language, and the time variable have a negative effect on the hazard rate. We present the results for the countries that have already had four agreements in column five. Only distance and common language have significantly negative effect. The effect of border and language is insignificant. Similar results are also found in column six and seven. The results indicate that conditional on having a relatively large number of agreements (more than four) only distance matters for the hazard of having another one.

In the last column, we pooled all the observations together and control for the number of agreements they already have. Distance and common language have a significantly negative effect. The effect of the time variable is also negative. The variable

MEA has a positive effect on the hazard (the same for other tables). It implies that countries with more environmental agreements are more likely to have another one in the following period. The reason may be that the more agreements they have the more familiar they become with the procedure of negotiation. So they can cooperate on environmental issues much faster.

In Table 4.2, we add GDP variables in our regressions. The sum of GDPs always has a positive effect on the hazard and the difference of GDPs has a negative effect except for column 2. Economically large countries tend to have more economic interactions with each other after controlling for other factors which may promote their cooperation on environmental issues. As a result, we expect that the sum of GDPs should have a positive effect on the hazard. Except for the results in column 2, the sum of GDPs always has a positive effect. Conditional on already having one MEA, the effect of GDPs on having another agreement is negative. The possible reason is that economically larger countries often have their first agreement in early years like 1960s or 1970s. However, most pollution agreements enter into force in 1990s. These relatively large countries may wait for a longer time to have their second agreement. On the other hand, countries with small economic sizes may have both their first and second agreement in 1990s, so the length of time between the first and second agreements is shorter for the small countries. In Tables 4.3 and 4.4, we add a trade agreement dummy and different types of trade agreements. As we can see, in general, a trade agreement has a positive effect on the hazard and deeper economic integration has a larger effect on hazard than one-way or two-way PTAs. In Table 4.5, we add a trade flow variable and it also has a positive effect on the hazard.

Table 4.2 Gravity variables with GDPs

VARIABLES	1 Conditional on MEA=0	2 Conditional on MEA=1	3 Conditional on MEA=2	4 Conditional on MEA=3	5 Conditional on MEA=4	6 Conditional on MEA=5	7 Conditional on MEA=6	8 Polled regression
SUM_GDP	0.0426***	-0.0434***	0.0244***	0.0662***	0.0317***	0.0588***	0.0456***	0.0163***
	(0.00192)	(0.00190)	(0.00196)	(0.00244)	(0.00292)	(0.0182)	(0.00448)	(0.000754)
DIFF_GDP	-0.00928***	0.0258***	-0.00131	-0.0128***	0.00768*	0.0361**	0.0216***	0.0125***
	(0.00234)	(0.00304)	(0.00321)	(0.00375)	(0.00449)	(0.0146)	(0.00685)	(0.00118)
DISTANCE	-0.133***	0.0935***	-0.0876***	-0.127***	-0.133***	-0.270***	-0.161***	-0.0678***
	(0.00686)	(0.00874)	(0.00905)	(0.0106)	(0.0117)	(0.0848)	(0.0177)	(0.00322)
BORDER	-0.184***	0.203***	-0.0637	-0.190***	-0.0796	-0.224	-0.171*	-0.0960***
	(0.0389)	(0.0513)	(0.0514)	(0.0582)	(0.0663)	(0.166)	(0.0998)	(0.0181)
COMMON LANGUAGE	-0.0589***	0.0344**	-0.109***	0.0251	0.0468*	0.143**	0.00578	-0.0312***
	(0.0124)	(0.0164)	(0.0172)	(0.0205)	(0.0252)	(0.0700)	(0.0393)	(0.00636)
ln_t	1.635***	-0.0417***	-0.0313***	-0.107***	-0.0983***	0.455	-0.116***	-0.181***
	(0.0256)	(0.00695)	(0.00797)	(0.00950)	(0.0116)	(0.326)	(0.0192)	(0.00224)
MEA								0.0224***
								(0.00135)
Constant	-7.014***	-0.841***	-0.494***	-1.151***	-0.487***	-0.605**	-0.697***	-0.753***
	(0.114)	(0.0865)	(0.0901)	(0.106)	(0.118)	(0.281)	(0.179)	(0.0328)
Observations	392,960	58,329	53,640	49,076	31,993	22,903	13,749	640,439
Number of country pairs	18,337	12,115	12,089	10,978	7,100	5,001	3,137	72,836

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.3 Gravity variable with EIA

VARIABLES	1 Conditional on MEA=0	2 Conditional on MEA=1	3 Conditional on MEA=2	4 Conditional on MEA=3	5 Conditional on MEA=4	6 Conditional on MEA=5	7 Conditional on MEA=6	8 Polled regression
SUM_GDP	0.0584***	-0.0476***	0.0295***	0.0720***	0.0313***	0.0482***	0.0405***	0.0107***
	(0.00273)	(0.00199)	(0.00211)	(0.00259)	(0.00308)	(0.0133)	(0.00471)	(0.000794)
DIFF_GDP	-0.0239***	0.0212***	0.00158	-0.00872**	0.00675	0.0262**	0.0152**	0.00442***
	(0.00279)	(0.00314)	(0.00330)	(0.00387)	(0.00465)	(0.0121)	(0.00710)	(0.00122)
DISTANCE	-0.127***	0.104***	-0.107***	-0.147***	-0.135***	-0.237***	-0.145***	-0.0492***
	(0.00844)	(0.00890)	(0.00931)	(0.0109)	(0.0120)	(0.0633)	(0.0184)	(0.00334)
BORDER	-0.219***	0.219***	-0.0649	-0.193***	-0.0998	-0.176	-0.166*	-0.0895***
	(0.0452)	(0.0519)	(0.0523)	(0.0587)	(0.0666)	(0.152)	(0.0997)	(0.0184)
COMMON LANGUAGE	-0.0502***	0.0209	-0.111***	0.0277	0.0432*	0.124**	-0.000421	-0.0396***
	(0.0141)	(0.0164)	(0.0174)	(0.0206)	(0.0252)	(0.0614)	(0.0393)	(0.00646)
TRADE AGREEMENT	0.0303**	0.0988***	-0.106***	-0.0880***	0.0153	0.147***	0.112***	0.131***
	(0.0143)	(0.0154)	(0.0162)	(0.0181)	(0.0208)	(0.0510)	(0.0309)	(0.00619)
ln_t	1.846***	-0.0419***	-0.0200**	-0.104***	-0.0991***	0.386	-0.117***	-0.178***
	(0.0388)	(0.00699)	(0.00807)	(0.00957)	(0.0116)	(0.245)	(0.0192)	(0.00226)
MEA								0.0116***
								(0.00138)
Constant	-8.008***	-0.854***	-0.404***	-1.073***	-0.456***	-0.619**	-0.761***	-0.777***
	(0.161)	(0.0871)	(0.0910)	(0.107)	(0.119)	(0.264)	(0.180)	(0.0334)
Observations	347,688	57,596	52,890	48,748	31,895	22,847	13,745	593,190
Number of country pairs	17,228	12,030	11,999	10,946	7,079	4,993	3,136	71,488

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.4 Gravity variables with various EIAs

VARIABLES	1 Conditional on MEA=0	2 Conditional on MEA=1	3 Conditional on MEA=2	4 Conditional on MEA=3	5 Conditional on MEA=4	6 Conditional on MEA=5	7 Conditional on MEA=6	8 Polled regression
SUM_GDP	0.0607***	-0.0445***	0.0263***	0.0691***	0.0318***	0.0541***	0.0437***	0.0139***
	(0.00269)	(0.00196)	(0.00204)	(0.00253)	(0.00299)	(0.0175)	(0.00459)	(0.000781)
DIFF_GDP	-0.0233***	0.0265***	-0.00179	-0.0119***	0.00865*	0.0346**	0.0197***	0.00903***
	(0.00277)	(0.00311)	(0.00326)	(0.00383)	(0.00458)	(0.0143)	(0.00700)	(0.00121)
DISTANCE	-0.129***	0.123***	-0.108***	-0.148***	-0.131***	-0.243***	-0.151***	-0.0447***
	(0.00874)	(0.00937)	(0.0101)	(0.0118)	(0.0128)	(0.0816)	(0.0198)	(0.00357)
BORDER	-0.203***	0.172***	-0.0516	-0.184***	-0.117*	-0.195	-0.179*	-0.103***
	(0.0460)	(0.0524)	(0.0527)	(0.0593)	(0.0673)	(0.157)	(0.1000)	(0.0186)
COMMON LANGUAGE	-0.0542***	0.0145	-0.115***	0.0279	0.0436*	0.129*	0.00329	-0.0382***
	(0.0143)	(0.0165)	(0.0174)	(0.0207)	(0.0253)	(0.0661)	(0.0393)	(0.00647)
OWPTA	-0.000325	0.0254	-0.0678***	-0.0626***	-0.00843	0.0372	0.0725*	0.0846***
	(0.0188)	(0.0206)	(0.0217)	(0.0240)	(0.0270)	(0.0440)	(0.0374)	(0.00836)
TWPTA	-0.0796**	0.221***	-0.184***	-0.178***	-0.104*	-0.0250	0.157*	0.115***
	(0.0340)	(0.0375)	(0.0374)	(0.0469)	(0.0572)	(0.130)	(0.0802)	(0.0149)
FTA_deeper	0.244***	0.365***	-0.0300	-0.0364	0.117**	0.139*	0.0466	0.188***
	(0.0591)	(0.0494)	(0.0419)	(0.0438)	(0.0460)	(0.0831)	(0.0555)	(0.0147)
ln_t	1.855***	-0.0406***	-0.0226***	-0.106***	-0.0986***	0.396	-0.116***	-0.179***
	(0.0384)	(0.00700)	(0.00806)	(0.00956)	(0.0116)	(0.313)	(0.0192)	(0.00227)
MEA								0.0104***
								(0.00142)
Constant	-8.060***	-1.087***	-0.330***	-1.008***	-0.510***	-0.680**	-0.760***	-0.870***
	(0.163)	(0.0922)	(0.0988)	(0.116)	(0.126)	(0.287)	(0.192)	(0.0354)
Observations	345,113	57,596	52,890	48,747	31,894	22,846	13,745	590,611
Number of country pairs	17,226	12,030	11,999	10,945	7,079	4,993	3,136	71,485

Standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1

Table 4.5 Gravity variables with EIA and trade

VARIABLES	1 Conditional on MEA=0	2 Conditional on MEA=1	3 Conditional on MEA=2	4 Conditional on MEA=3	5 Conditional on MEA=4	6 Conditional on MEA=5	7 Conditional on MEA=6	8 Polled regression
SUM_GDP	0.0420***	-0.0438***	0.0302***	0.0684***	0.0260***	0.0481***	0.0539***	0.00136
	(0.00273)	(0.00242)	(0.00262)	(0.00320)	(0.00382)	(0.0116)	(0.00610)	(0.000937)
DIFF_GDP	-0.0235***	0.0205***	0.00150	-0.00854**	0.00713	0.0217**	0.0143**	0.00519***
	(0.00280)	(0.00315)	(0.00330)	(0.00387)	(0.00466)	(0.0102)	(0.00711)	(0.00122)
DISTANCE	-0.117***	0.101***	-0.107***	-0.143***	-0.132***	-0.208***	-0.161***	-0.0424***
	(0.00841)	(0.00896)	(0.00938)	(0.0111)	(0.0121)	(0.0520)	(0.0189)	(0.00336)
BORDER	-0.225***	0.220***	-0.0651	-0.194***	-0.102	-0.160	-0.175*	-0.0896***
	(0.0451)	(0.0519)	(0.0523)	(0.0587)	(0.0666)	(0.129)	(0.0999)	(0.0184)
COMMON LANGUAGE	-0.0793***	0.0261	-0.110***	0.0223	0.0342	0.117**	0.00885	-0.0532***
	(0.0142)	(0.0165)	(0.0175)	(0.0208)	(0.0255)	(0.0522)	(0.0394)	(0.00651)
TRADE AGREEMENT	-0.0433***	0.107***	-0.104***	-0.0961***	0.00496	0.140***	0.135***	0.102***
	(0.0148)	(0.0157)	(0.0167)	(0.0186)	(0.0213)	(0.0454)	(0.0317)	(0.00639)
SUM TRADE	0.0121***	-0.00176***	-0.000332	0.00155*	0.00217**	-0.00285*	-0.00523***	0.00503***
	(0.000632)	(0.000647)	(0.000736)	(0.000813)	(0.000912)	(0.00161)	(0.00151)	(0.000267)
ln_t	1.881***	-0.0405***	-0.0198**	-0.106***	-0.100***	0.234	-0.108***	-0.180***
	(0.0404)	(0.00701)	(0.00809)	(0.00960)	(0.0116)	(0.206)	(0.0194)	(0.00227)
MEA								0.00495***
								(0.00143)
Constant	-7.977***	-0.887***	-0.410***	-1.046***	-0.404***	-0.639***	-0.820***	-0.683***
	(0.164)	(0.0880)	(0.0921)	(0.108)	(0.121)	(0.226)	(0.181)	(0.0337)
Observations	347,688	57,596	52,890	48,748	31,895	22,847	13,745	593,190
Number of country pairs	17,228	12,030	11,999	10,946	7,079	4,993	3,136	71,488

Standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1

4.4.2 Fitted Hazard Rates Over Time

In this section, we present the plots of the estimated hazard rates over time. We first discuss the fitted hazards generated by using all pollution agreements which is followed by the discussion of the fitted hazards of small agreements and large ones separately. We use the specification in Table 4.3, which includes gravity and trade agreement variables, to calculate all the estimated hazard rates. Our results show that the hazard of having the first agreement increases over time, and the hazard of having another agreement conditional on already having some decreases over time. The hazard of having an additional agreement (2^{nd}, 3^{rd}, and etc.) is always larger than the hazard of having the first one.

In Figure 4.3, we plot the fitted hazards of having the first agreement with solid line and the fitted hazard of having the second one with a dashed line. We focus on the hazard of signing an agreement over a period of 20 years. As we can see, the estimated hazard of having the first agreement increases over time, while the estimated hazard of having the second one decreases over time. The results indicate that conditional on having no agreement the longer two countries wait the more likely they are to sign an agreement. And after they already have one agreement, the longer they wait the less likely they are to have another one. As we discussed before, pollution agreements are often costly and the realization of true economic costs of implementing an agreement takes time, the longer they wait the less likely they would cooperate on an additional one. Another point worth mentioning is that the level of the hazard of having the second agreement is always larger than that of the first one.

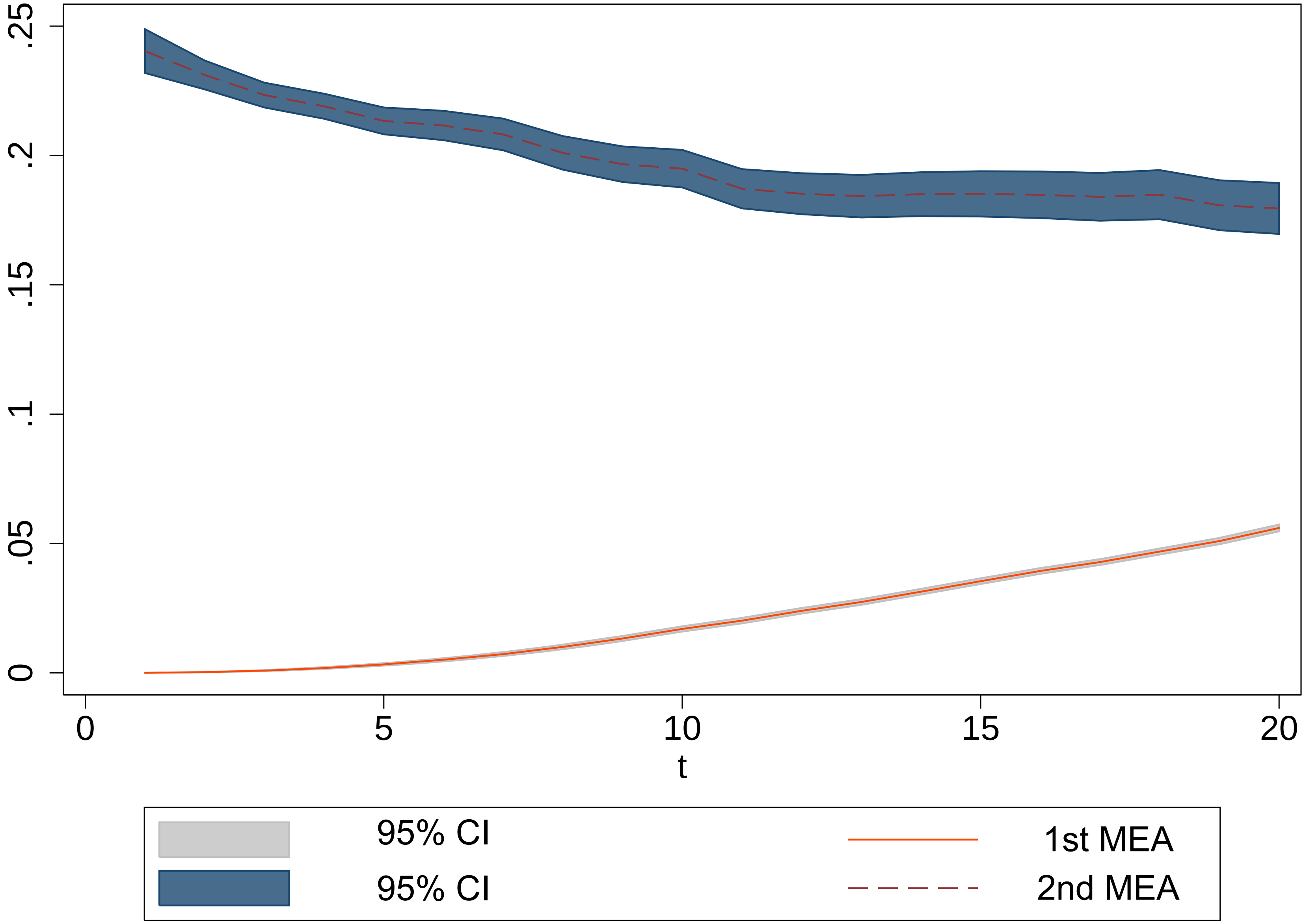

Figure 4.3 Fitted Hazard of Having 1st and 2nd Agreements

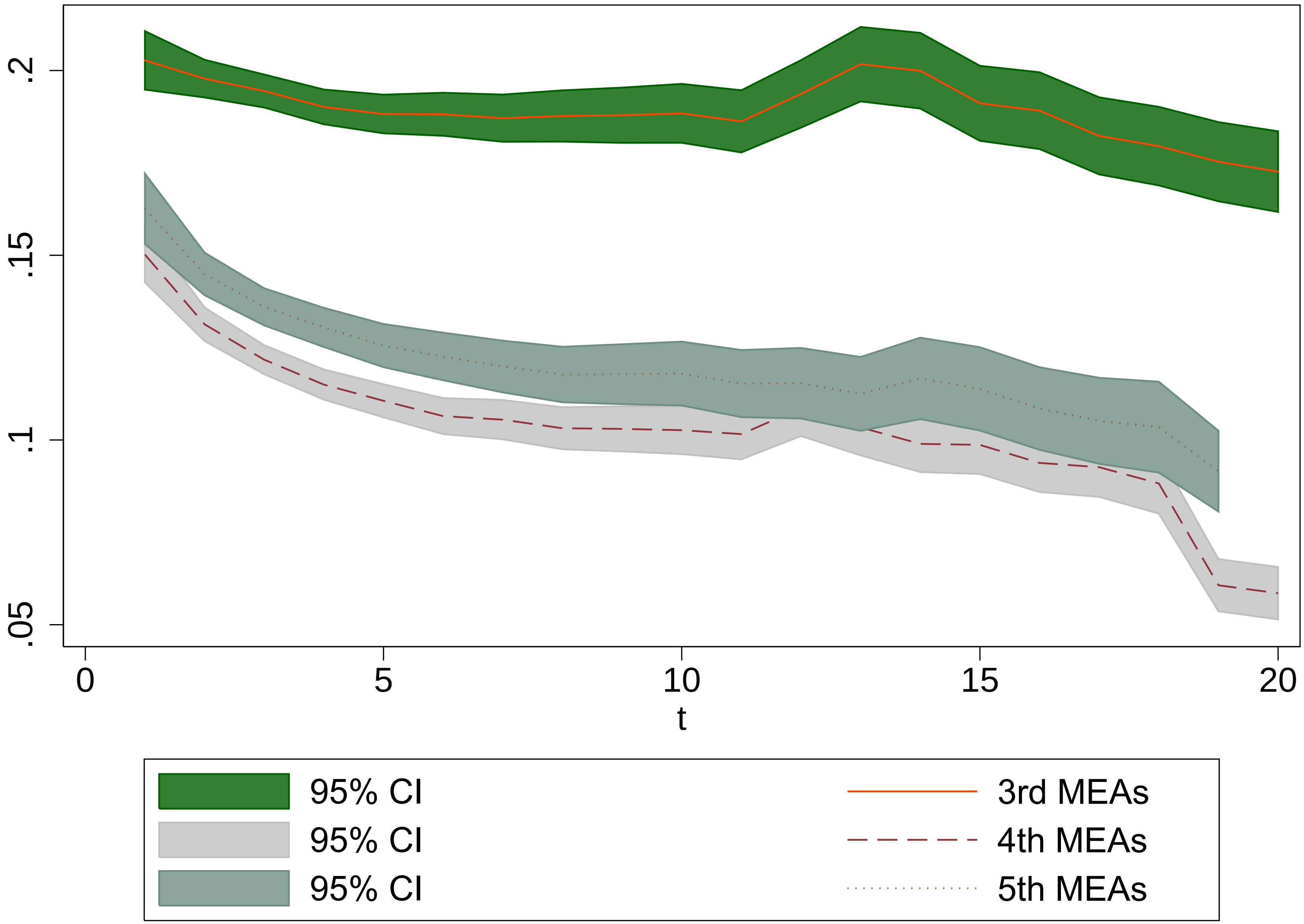

Figure 4.4 Fitted Hazard of Having 3rd, 4th, and 5th Agreements

We plot the fitted hazards of having the third, fourth, and fifth agreements for a period 20 years in Figure 4.4. In general, the hazards decrease over time, indicating that the longer the countries wait to sign another agreement, the less likely they are to sign it. The magnitude of the hazard of the third agreement is larger than that of the fourth and fifth agreement. The overlapped confidence intervals indicate that we cannot clearly distinguish the level of the hazards of having the fourth and fifth one. To have a better idea on the magnitudes of various hazards, we calculate the average estimated hazards in Figures 4.3 and 4.4 over time in Table 6. The first column shows the average values of various hazards in 20 years, while the second and third columns show the average values in the first and second 10 years respectively. In general, after having a number of agreements the hazard of having another one is always higher than the hazard of having the first agreement. In addition, the hazards of having the second and third ones are larger than that of having the fourth and fifth.

Table 6 Average Fitted Hazard

Average Fitted Hazard	First 20 Years	First 10 Years	Next 10 Years
1st Agreement	0.02166915	0.0058932	0.0374451
2nd Agreement	0.1989896	0.2139233	0.1840559
3rd Agreement	0.18922105	0.1912714	0.1871707
4th Agreement	0.10274305	0.1149676	0.0905185
5th Agreement	0.1138961	0.1295547	0.0982375

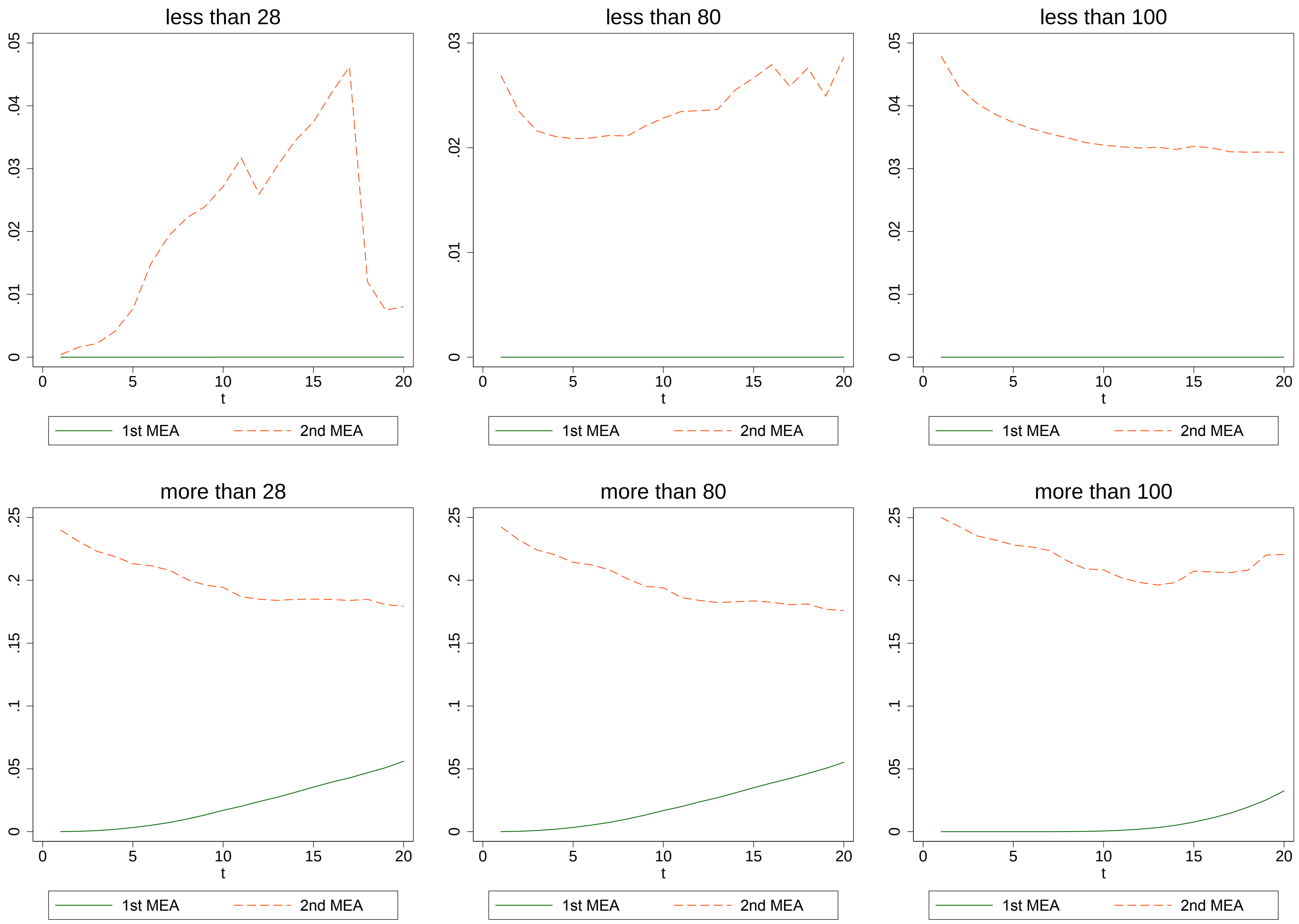

Figure 4.5 Fitted Hazards of Having the 1st and 2nd Agreement Based on Size

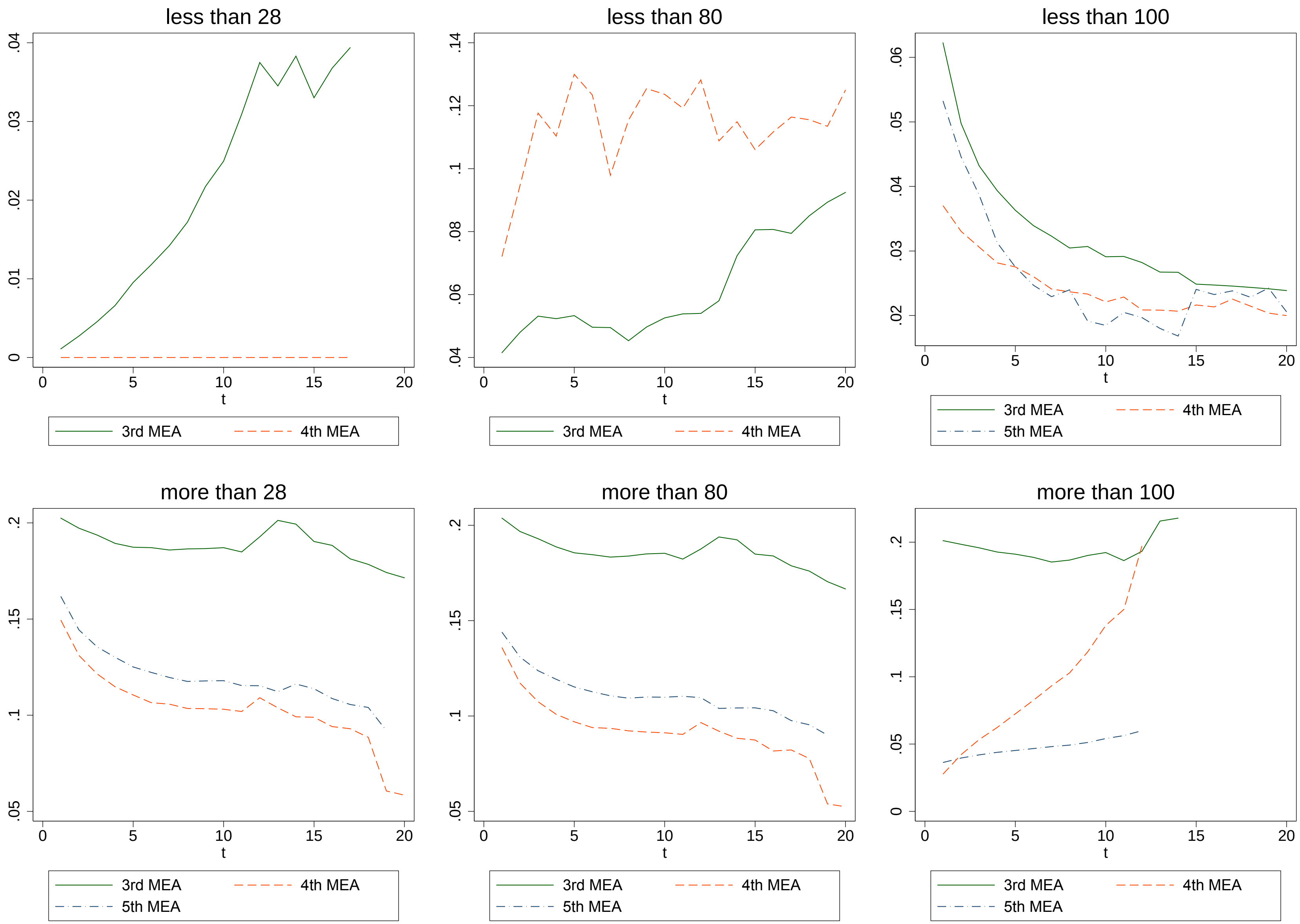

Figure 4.6 Fitted Hazards of Having the 3rd, 4th, and 5th Agreement Based on Size

In Figures 4.5 and 4.6, we examine the pollution agreements based on the number of signatories they have. Specifically, we focus on the agreements with less than 20 signatories, 80 signatories, and 100 signatories and those with more than 20, 80, and 100 signatories. Figure 4.5 shows the estimated hazards of having the first and second agreements and Figure 6 show the estimated hazards of having third, fourth, and fifth ones. In Figure 4.5, the hazard of having the first small agreement is much lower than the hazard of having a large one which indicates that countries may incur fewer economic costs when they cooperate on large agreements than small ones. The environmental agreements with a large number of signatories are often symbolic and do not have binding commitments. So the costs of implementing large agreements tend to be small and countries may be more likely to cooperate on such agreements. Similar to our previous results, the hazard of having an additional agreement is always larger than the hazard of having the first one no matter whether the agreements are large or small.

4.5 Conclusion

In this chapter we explore the economic determinants of timing of pollution related agreements. Specifically, we examine how long it takes two countries to have their first pollution agreement since 1950 and how long it takes them to have another agreement conditional on already having had some. The pollution agreement data used in our analysis mainly address air pollution, marine pollution, and waste pollution and they are from Ronald Mitchell's International Environmental Agreement Database Project (2002-2016). Following the method developed by Hess and Persson (2012), we employ a discrete-time duration model to examine the hazard of two countries' cooperation on pollution agreements in the period 1950 to 2005. We focus on all the pollution agreements in our sample, as well as the agreements with a small number of signatories and those with a large number of signatories.

Our results show that economic size, distance, and trade integration variables shift the hazard of two countries having their first agreement or another one. In addition, the time variable has a positive effect on the hazard conditional on two countries having no agreements before, but the effect changes to be negative if two countries already have some agreements. Furthermore, countries' likelihood of cooperating on an additional agreement is much larger than the likelihood of having their first one. In the future, we will examine the timing of pollution agreements addressing a certain type of polluting issue such as air pollution. Also, we can divide all agreements into regional pollution agreements and global pollution agreements, and separately examine the timing of these two types of agreements.

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